ELEMENTS OF AGRICULTURE

A TEXT-BOOK PREPARED UNDER THE AUTHORITY OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND

BY THE LATE

W. FREAM, LL.D.

TENTH EDITION

(SEVENTY-NINTH THOUSAND)

EDITED BY

J. R. AINSWORTH-DAVIS, M.A., (TRIN. COLL. CAMB.).

PRINCIPAL OF THE ROYAL AGRICULTURAL COLLEGE, CIRENCESTER, AND PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF BRISTOL.

LONDON

JOHN MURRAY, ALBEMARLE STREET, W.

1919.

PRINTED BY
JAS. TRUSCOTT AND SON, LTD.
SUFFOLK LANE, LONDON,
E.C.

PREFACE

TO THE

EIGHTH EDITION

of the Royal Agricultural Society's Text Book, 1911

THE Text-Book edited by the late Dr. Fream and published, having run through seven editions, and met with so great a demand by the public that 39,000 copies have been sold since its issue, the Society thought the time had arrived for a thorough revision and partial rewriting of the book, this being placed in the hands of Professor J. R. Ainsworth-Davis, Principal of the Royal Agricultural College, Cirencester. Assisted by Dr. Voelcker, Mr. R. M. Greaves, Mr. Cecil Warburton. Professor Drysdale Turner, Mr. C. D. Stewart, Mr. Ernest Mathews, Mr. G. H. Hollingworth, Mr. W. H. Neild, Mr. J. Herbert Taylor, Mr. W. Hanson Sale, Mr. Sanders Spencer, and the Secretaries of the Breeding Societies, Professor Ainsworth-Davis has spared no pains to bring Dr. Fream's work up to the present date. The plates are taken from photographs of representative animals, and the Society wish to thank those gentlemen who have been good enough to provide them.

The thanks of the Society are especially due to Professor Ainsworth-Davis for undertaking the somewhat ungrateful task of building upon another man's foundations, and they trust that the gratitude of all interested in Agricultural Education will be some reward for his arduous labours.

J. H. THOROLD,
Chairman of the Education Committee.

ROYAL AGRICULTURAL SOCIETY OF ENGLAND,
16, Bedford Square, W.C.
July, 1911.

EXTRACTS FROM THE PREFACE TO THE FIRST EDITION

The preparation of this Text-Book was undertaken by the Royal Agricultural Society of England, in compliance with the many demands that had been addressed to it for an elementary work on Agriculture adapted for use in rural and other schools and classes.

The general scheme of the work was settled by a Sub-Committee appointed by the Council of the Society, and consisting of Lord Moreton (Chairman), Major Craigie, Mr. C. De L. Faunce De Laune, Mr. D. Pidgeon, Mr. Martin J. Sutton, and Mr. Charles Whitehead.

The Sub-Committee placed the preparation of the Text-Book in the capable hands of Dr. W. Fream, to whose skill and knowledge of the subject any success which the work may attain will be chiefly due.

The Sub-Committee desire also to record their grateful acknowledgments, for valuable suggestions and revision of the proof-sheets, to Sir John Lawes, Bart., Sir John Thorold, Bart., Sir Jacob Wilson, Mr. Alfred Ashworth, Mr. Thomas Bell, Mr. J. Bowen-Jones, Mr. Chandos-Pole-Gell, Dr. J. H. Gilbert, Miss E. A. Ormerod, Mr. D. Pidgeon, Mr. Clare Sewell Read, and Dr. Voelcker.

TABLE OF CONTENTS

PART I.—THE SOIL

CHAPTER | PAGE

I. FORMATION OF SOIL 1

Soil and subsoil, 1; kinds of soil, 2; native plant growth, soluble and insoluble soil constituents, 3; geological maps, formation of soil from rocks, disintegration, 4; water as an agent of disintegration, 5; igneous and aqueous rocks, 7; weathering, sedentary soils, 8; transported soils, constant change in soils, earthworms, 9.

II. COMPOSITION AND CLASSIFICATION OF SOILS . . 10

Mineral and organic matter, sand, 10; clay, 11; lime, 12; limestone, humus, 13; green manuring, classification of soils, 14; mechanical analysis of soils, 16; chemical analysis of soils, 17; availability of plant foods, 18; analyses of soils, 20.

III. PHYSICAL PROPERTIES OF SOILS 22

Structure of soil, 22; air and water of soil, 23; capillarity, tilth, water-table, 25; mulches, 26; pans, 27; temperature of soil, 28.

IV. SOURCES OF LOSS AND GAIN TO SOILS . . . 29

Composition of drainage waters, 30; washing out of nitrates, 31; bare fallow, 32; sources of gain, 33; agents of disintegration, rain, 34; dew and hoar-frost, composition of rain, 36; residues of crops, humus, 37; organic nitrogen, nitrification, 38; nitrogen-fixing bacteria, 39; denitrification, fungi of soil, 40; mycorhiza, symbiosis, 41.

CHAPTER PAGE

V. IMPROVEMENT OF SOILS 41
Poor soils, 41; lime, marl, warping, paring and burning, 42; green manuring, draining, 43; natural and artificial drainage, 44; acts of tillage, 46.

VI. AGRICULTURAL IMPLEMENTS 46
(1) Implements for working soils, 46; the plough, 47; ploughing, 53; points of good ploughing, types of plough, 57; cultivators, 62; harrows, 63; rollers and pressers, 64. (2) Implements for sowing seed and distributing manure, drills, 66; artificial manure distributors. (3) Steam cultivation, 69. (4) Implements for securing crops, harvesting implements, reaping machines, 71; mowing machines, 74; haymaking machine, haykicker, swathe turner, horse-rake, 76; elevator or stacker, 77; hay and straw presses, carts and waggons, 79. (5) Implements for preparing crops for market, threshing machines, 80; steam engines, oil engines, 85; petrol engines, 86; winnowing machines, 87; screens, 88. (6) Implements for preparing food for stock, chaff cutters, 89; turnip-cutters or pulpers, corn grinding mills, 91. (7) Hand implements, spade, shovel, forks, 92; rakes, 93; hoes, scythe, 94; sickle, fagging hook, 96; pea-hook, hedge-slasher or switch bill, 97.

VII. TILLAGE 97
Preparation of a tilth, ploughing, cultivating, harrowing, rolling, 98; hoeing, autumn cultivation, 99; winter and spring cultivation, 100; summer cultivation, cleaning land, 101; features of a good tilth, differences between cultivation of heavy and light soils, 103; after cultivation or intertillage, 104; objects of tillage, 105.

VIII. MANURES AND MANURING 105
Manuring land through stock, 105; farmyard manure, 107; artificial manures, 111; fertility and condition of soil, Peruvian guano, 112; fish guano, bones, 113; mineral superphosphate, 114; basic slag, 117; nitrate of soda, 118; sulphate of ammonia, calcium cyanamide, calcium nitrate, 119; manures made from animal refuse, soot, 120; other organic manures, potash manures, common salt, 121; gypsum, application of artificial manures, 122; manures for special crops, 123.

PART II.—THE PLANT

CHAPTER PAGE

IX. SEEDS AND THEIR GERMINATION 127

Structure of broad bean seed, 127; factors of germination, 128; root and shoot, 130; plant food, 131; seeds like the bean, structure and germination of wheat grain, 132; albuminous and exalbuminous seeds, 135; chlorophyll, malting, 136; ferments (enzymes), carbohydrates, fats, and oils, 137; proteins, seeds as storehouses, 138.

X. STRUCTURE AND FUNCTIONS OF PLANTS—ROOTS, STEMS, AND LEAVES 139

Shoot and root, 139; branching form of green plants, protoplasm, metabolism, 140; food and feeding, chlorophyll, 142; breathing or respiration, 143; roots, general character and structure, 144; kinds of root, functions of roots, 145; osmosis, 147; water culture, stems, general character and structure, 148; nodes and internodes, kinds of stem, 149; climbing stems, stolons, 150; runners, underground stems, tubers, 151; bulbs, corms, rhizomes or root stocks, 152; suckers, 154; functions of stems, leaves, general character and kinds, foliage leaves, 155; structure of foliage leaves, 156; functions of foliage leaves, 158; duration of life, annuals, 159; biennials, 160; perennials, storage of plant food, 161.

XI. STRUCTURE AND FUNCTIONS OF PLANTS—FLOWERS, FRUITS, AND SEEDS 162

Structure and function of flowers, 162; pollination and fertilization, 164; flowers and insects, self and cross-pollination and fertilization, 165; cruciferous flowers, 166; papilionaceous flowers, 167; dichogamy, 169; incomplete flowers, dicotyledons and monocotyledons, 170; cross-pollination and cross-fertilization, 171; inflorescences, artificial pollination, 173; self-pollination and self-fertilization, fruits and seeds, 174; kinds of fruit, 175; spurious fruits, dispersal of seeds, 177.

XII. CULTIVATED PLANTS 178

(1) Cruciferæ, 179; turnips and swedes, 180; rape, 182; cabbage, 183; mustard, cress, charlock, radish, 186; horse - radish, watercress. (2) Caryophyllaceæ, chickweed, 187; corn cockle,

CHAPTER PAGE

XII. CULTIVATED PLANTS—*continued.*

spurrey, 188. (3) Linaceæ, flax, 189. (4) Leguminosæ, pulses, peas, 190; beans, 191; clovers, white or Dutch clover, 192; red or broad clover, 193; cow grass, 194; alsike, crimson clover or "trifolium," 195; yellow suckling clover, hop trefoil, 196: trefoil or yellow clover, lucerne, 197; sainfoin, 198; vetches or tares, 199; birdsfoot trefoil, 200; kidney vetch, Bokhara clover, 201; lupines, gorse, serradella, fenugreek. (5) Rosaceæ, 202; stone fruits, strawberry, apple and pear. (6) Ribesiaceæ, gooseberry and currant, 203. (7) Cucurbitaceæ, cucumber, vegetable marrow, etc. (8) Umbelliferæ, 204; carrot, 205,; parsnip, celery, parsley, sheep's parsley, fennel, caraway, 206; weed umbellifers, 207; poisonous umbellifers, 208. (9) Compositæ, 209; yarrow, 210; chicory, lettuce, 211; dandelion, sunflower, Jerusalem artichoke, globe artichoke, compositaceous weeds, 212. (10) Solanaceæ, 213; potato, poisonous solanaceous plants, tomato, 214; egg plant. (11) Labiatæ, pot herbs and weeds. (12) Boragineæ, prickly comfrey, boraginaceous weeds, 215. (13) Chenopodiaceæ, 216, mangel wurzel, garden beet, sugar beet, 217. (14) Polygonaceæ, buckwheat, rhubarb, polygonaceous weeds, 218. (15) Urticaceæ, hop, 219. (16) Liliaceæ, onion, 220; shallot, leek, asparagus, liliaceous weeds. (17) Gramineæ, 221; rushes (Juncaceæ), sedges (Cyperaceæ), 227; cocksfoot, 230; dogstail, 231; fescues, 232; bent grasses, 237; meadow foxtail, 238; floating and slender foxtail, 241; meadow grasses, 241; oat grasses, 243; rye grasses, 247; sweet grasses, 250; sweet-scented vernal grass, 251; Puel's vernal grass, 253; Timothy, 254; brome grasses, 256; couch grass, 257; wheat grass, hair grasses, 258; barley grasses, 259; quaking grass, Yorkshire fog, 259; creeping soft grass, 260; cereals, wheat, barley, 261; oats, rye, 262; maize, sorghum, canary grass, 263.

XIII. WEEDS 264

(1) Ranunculaceæ, buttercups, marsh marigold, pheasant's eye, wood anemone, 264. (2) Papaveraceæ, poppy, opium poppy, (3) Fumariaceæ, fumitory. (4) Geraniaceæ, cranesbills, 265. (5) Rubiaceæ, goosegrass, bedstraws, field madder.

CHAPTER PAGE

XIII. WEEDS—*continued.*

(6) Convolvulaceæ, bindweeds, 266; dodders, 267. (7) Scrophularineæ, snapdragon, foxglove, musk, toadflax, root parasites, figwort, mullein, speedwells, 268. (8) Orobanchaceæ, broom rapes, 269. (9) Primulaceæ, cowslip, primrose, scarlet pimpernel. (10) Plantagineæ, plantains, 270. (11) Juncaceæ. (12) Cyperaceæ; relation of weeds to agriculture, 271; preventive measures, 272; remedial measures, 273.

XIV. SELECTION OF SEEDS 274

Germinating capacity, 274; identity to species, impurities, 276; real value, collections of seeds, 277.

XV. GRASS LAND AND ITS MANAGEMENT 279

Temporary and permanent grass, pasture and meadow, 279; water meadows, 281; laying down land to grass, 283; mixtures for sowing land down to grass, 287; management of old pasture, 289; management of meadow land, 295; hay-making, 296; quality of hay, 301; ensilage, 303.

XVI. FARM CROPS 307

Grass land, arable land, 307; rotation of crops, 308. (1) Corn crops, wheat, 315; oats, 321; barley, 322; rye, 326. (2) Pulse crops, beans, 327; peas, 330. (3) Root crops, preparation of the land, 332; seeding of root crops, mangel wurzel, 336; swedes, 338; turnips, 339; carrots, parsnips, 340; subsequent cultivation and harvesting of roots, 341; characters of farm seeds, 342. (4) Cruciferous forage crops, rape, 344; kohl rabi, thousand-headed kale, cabbages, 345; white mustard. (5) Leguminous forage crops, vetches or tares, 346; trifolium, lucerne, 347; sainfoin, 348; trefoil, clovers and "seeds," 349. (6) Cultivation of potatoes, 351. Cost of growing crops in a rotation, 357.

XVII. HARDY FRUIT CULTURE. 360

Introduction, 360. (1) Apples and pears in grass orchards, 361; planting, 362; tying and protecting, pruning, 364; manuring orchards, varieties, 366; stone fruits in orchards, 367. (2) Mixed fruit plantations, 368; planting and cultivating, pruning half-standards, bush and pyramid trees, gooseberries, red currants, 370;

CHAPTER PAGE

XVII. Hardy Fruit Culture—*continued*.

black currants, raspberries, logan berries, manuring, 372; profitable varieties for plantations, 373. (3) Strawberries for market. (4) General considerations, 374. (5) Fruit in the garden, espaliers and cordons, strawberries in the garden, root pruning, 375; summer pruning. (6) Propagation of fruit, stocks, 376; budding, 377; grafting, 378; cuttings, 380; suckers, runners, 383.

XVIII. Fungus Pests 383

Thallophyta, mushroom, 383; yeast, moulds, 384; canker, saprophytes, parasites, 385; rusts, black rust, 386; heteroecism, 388; yellow rust, smut, oat smut, wheat smut, barley smut, 390; bunt, 392; ergot, 393; American gooseberry mildew, 395; potato disease, 396; white rust, 400; damping off, black scab or wart disease, 402; club root, 403; bacterial diseases, 405; methods of suppression, 406.

PART III.—THE ANIMAL

XIX. Structure and Functions of Farm Animals . 407

Vertebrata, mammalia, anatomy and physiology, the horse, regions of body, 407; skeleton, 408; hoof of the horse, 418; skeleton of the ox, 420; skeletons of sheep and pig, classification of farm animals, 422; muscular system, 423; metabolism, 424; digestive organs, 425; ruminant stomach, 427; rumination, 428; digestive juices, 429; classes of foodstuffs, 430; digestion, 432; circulatory organs, 434; blood system, 435; course of the circulation, 437; the pulse, 439; lymph system, 441; breathing or respiratory organs, 442; pure and impure blood, hæmoglobin, 443; respiratory movements, 444; necessity for ventilation, maintenance of the heat of the body, excretion, lungs, liver, skin, kidneys, 445; absorption of digested food, 447; gains and losses of the blood, nervous system, 450; sense organs, reproduction, 451.

XX. Composition of the Animal Body . . . 452

Bone, 453; connective tissue, cartilage, flesh, 454; fat, 455.

CHAPTER PAGE

XXI. Foods and Feeding 455

Maintenance diet, 455; modifications of diet, flavour, 456; composition of ordinary foods, 457; oil-cakes, 458; cereals, succulent foods, 459; sugar crops, 460; uses of fibre, 461; feeding value, 462; digestion co-efficient, albuminoid ratio, 463; principles of feeding, 464; data regarding foods, 465.

XXII. Principles of Breeding. 468

Species and varieties, 469; hybrids and mongrels, evolution and origin of species, 470; Darwinism, 471; heredity, 472; reversion, atavism, or throw-back, 473; prepotency and in-breeding, transmission of acquired characters, 474; variation, Mendelism, 475; general remarks on farm stock, 479; breed records, 480; gestation, 481.

XXIII. Horses: their Breeds, Feeding, and Management. 481

Thoroughbred, 481; hunter, 482; hackney, 483; pony, Cleveland bay, 484; coaching, shire, 485; Clydesdale, 486; Suffolk, feeding and management, 487; cost of horse labour, 490.

XXIV. Cattle: their Breeds, Feeding, and Management 492

Shorthorn, 493; Hereford, 496; North and South Devon, 497; Sussex, Welsh, longhorn, 498; red poll, 499; Aberdeen-Angus, 500; Galloway, 501; Highland, 502; Ayrshire, 503; Jersey, 504; Guernsey, 505; Kerry, 506; Dexter, 507; feeding and management, 508; Lincoln reds and British-Holsteins, 656.

XXV. Sheep, their Breeds, Feeding, and Management 513

Leicester, 514; Border Leicester, Cotswold, 515; Lincoln, Kent or Romney Marsh, 516; Oxford Down, Southdown, 518; Shropshire, Hampshire Down, 520; Suffolk, 521; Cheviot, 522; black-face mountain, Herdwick, 523; Ryeland, 524; Devon longwool, South Devon, 525; Dorset horn, 526; Lonk, 527; Dartmoor, Exmoor, Welsh mountain, Derbyshire gritstone, 528; limestone, Wensleydale, 529; Kerry Hill, 530; Clun Forest, Roscommon, feeding and management, 531.

CHAPTER PAGE

XXVI. PIGS: THEIR BREEDS, FEEDING, AND MANAGEMENT 535

Large white, 535; middle white, small white, 537; Berkshire, Tamworth, 538; large black, 539; small black, Lincoln curly-coated, feeding and management, 540.

XXVII. THE FATTENING OF CATTLE, SHEEP, AND PIGS . 543

Composition of carcases, 543; nitrogen and minerals in fasted live weights, 544; loss of mineral matter from stock, 545; composition of fattening increase, 546.

XXVIII. DAIRYING 548

(1) Milk, 548; blood and milk, 550; blood supply of mammary gland, composition of cow's milk, 551; cost of keeping a dairy cow, 554; milk records, 555; percentage of cream, 557; percentage of butter fat, 558; milking, 559; cleanliness, 560; treatment of milk, 561; separators, 563; starters, 565. (2) Butter, Pasteurization, cream, 567; churning, rules for butter-making, 568; centrifugal drying machine, 569; working and making up of butter, characters of good butter, 570; milk required to make 1 lb. of butter, cleaning the churn. (3) Cheese, rennet, 571; hard cheese making, Cheddar, 572; Stilton, 577; soft cheeses, single cream, 580; double cream, Cambridge or York, sour milk, 581; Pont L'Evêque, 582; Neufchâtel, Coulommier, 583; Gervais, 584.

XXIX. POULTRY AND POULTRY KEEPING . . . 584

Fowls, origin of domestic fowl, 584; classification of breeds, 585; description of common breeds, 586; ducks, origin, common breeds, 588; geese, origin, common breeds, 589; turkeys, origin, common breeds, fowl houses, 590; selection, mating, and breeding, 592; hatching and rearing, 593; feeding table, fattening, 599; ducklings, goslings, 600; turkeys, killing and dressing, 601; marketing of eggs, 604; preservation of eggs, 605; diseases, 606.

XXX. HARMFUL AND BENEFICIAL ANIMALS . . . 608

Groups of animals, 609. (1) Mammals, flesh-eating mammals (Carnivora), 610; gnawing mammals (Rodentia), 611; insect-eating mammals (Insectivora), 614. (2) Birds, 615; relation of birds to

CHAPTER PAGE

XXX. HARMFUL AND BENEFICIAL ANIMALS—*continued.*

agriculture, 616; beneficial birds, 617; harmful and doubtful birds. (3) Insects, 618; (*a*) Coleoptera, harmful and useful beetles, 620; (*b*) Hymenoptera, ichneumon flies, 622; bees, injurious hymenopterids, 623; (*c*) Lepidoptera, 624; butterflies, 625; moths, injurious lepidopterids, 626; (*d*) Homoptera and (*e*) Heteroptera, aphides, 628; lice, (*f*) Diptera, 630; injurious flies and fleas, 631; beneficial flies, (*g*) Orthoptera, 632; injurious orthopterids, Thrips, (*h*) Neuroptera, 633; harmful and beneficial neuropterids, mouths of insects, 634; mandibulate and haustellate insects, life histories of insects, 635; structure of insects, identification of larvæ, 636; insect attacks, 637; natural enemies of insects, 639; preventive and remedial measures, 640. (4) Arachnids, spiders and mites, 644. (5) Myriapods (centipedes and millipedes). (6) Round worms (Nemathelmia), 646. (7) Flat worms (Platyhelmia), 649; flukes (Trematoda), 650; tapeworms (Cestoda), 651. (8) Animalcules (Protozoa), 653.

ADDENDUM.—Lincolnshire red shorthorn and British-Holstein cattle 656

INDEX 657

bare the subsoil and expose the latter to the air, in the course of time the surface of the subsoil would change into soil. Hence, there is a relationship between these two, and the soil may be regarded as derived from the subsoil. The chief agents in effecting the change are air, moisture, and changes of temperature, aided by plants and animals.

That there are **different kinds of soil** is a fact that everybody can prove for himself. The differences are visible to the eye; they are felt when the soils are walked upon, and still more so when portions are taken up and handled; and they declare themselves by the sorts of plant which grow naturally upon the soils. Visible differences are those of colour, and, to some extent, of texture. Red soils may be seen in Somerset and Herefordshire, bluish soils in Gloucestershire, dirty white or greyish soils in parts of the Thames valley and in Kent, yellowish soils in Northamptonshire, and black soils in the Fens of Lincolnshire, and in most kitchen gardens. Some soils are seen to have a loose texture, and these may be either fine or coarse, ranging from sandy to gravelly or stony. Others are seen to possess a close, firm texture, and to allow water to rest in puddles upon their surface, as is the case with most of the clay soils.

Much is learnt about a soil by merely walking upon it. What is called a loose open soil shifts beneath the feet, but shows no tendency to adhere to the boots; such a soil is usually dry. What is termed a stiff tenacious soil retains the imprint of the foot and is very adhesive, so that when such a soil is wet it is not possible to walk across it with much rapidity. All clay soils partake more or less of this character.

By handling a soil, other facts may be learnt concerning it. A dry loose soil will run through the spaces between the fingers if a handful of it is taken up. Even moistening it with water will not cause it to cohere for any length of time. The many kinds of clay soils, on the contrary, are so tenacious that they can be moulded by the hand, provided they are sufficiently moist. By rubbing portions of a soil between the thumb and

finger further information is obtained as to its texture, for it will be felt whether the particles are fine and unctuous (soapy or greasy) as in a clay, or coarse and gritty as in a sandy soil.

The wild or **native plant growth** upon a soil is always worthy of notice where it can be observed. Heather, whortleberry, bracken, larches, and fir-trees, are the natural produce of poor barren sands often stretching away into heaths and moors. Oak-trees and cowslips thrive upon clay soils, while beech and yew-trees do well upon chalk or other limestone soils. Oaks, therefore, flourish upon the clay soils which extend far up the valley of the Thames, and occupy large areas in the heart of Kent and Sussex. The beech and the yew may be seen in plenty upon the Chalk Downs of the South of England. Rushes, sedges (including cotton-grass), and sundew grow in many localities where the land is wet and marshy.

The foregoing examples serve to show that, with ordinary care, it is possible to learn many useful facts about a soil, without calling in the aid of special means of observation.

That part of a soil which dissolves in water is called the **soluble** part, whilst that which will not dissolve is called the **insoluble** part. The distinction is important, because plants, in obtaining food from the soil (which they do by means of their roots) only make use of the soluble part there present. When water which has trickled through a soil flows away from it, some of this soluble matter—and in certain cases a considerable proportion of it—may be drained away.

It is thus possible to learn by very simple means of observation that soils vary in colour, in texture, and in the plants they naturally produce; also that they contain variable proportions of moisture, and that whilst a part of the soil is soluble in water, by far the larger proportion of it is insoluble.

The soil, as seen in arable fields and gardens, is the **final product of a long series of changes**, the study of which belongs to the science of Geology. If the land could be suddenly stripped of its soils and subsoils,

there would be exposed rock surfaces very different in character from the soils by which they are covered. The colours upon an ordinary map of the 'solid geology' of any area are intended to indicate the nature of these underlying rock-masses, which can always be reached by digging down to a sufficient depth. On the North and South Downs, on Salisbury Plain, on the slopes of the Chiltern Hills, in the western parts of Norfolk and Suffolk, and elsewhere, the underlying rock is chalk. In parts of Northumberland, Durham, Yorkshire, and Lancashire, on either side of the Pennine Chain, it is a hard limestone. In Gloucestershire, Oxfordshire, and other midland counties of England it is often a stiff bluish or yellowish clay—to the geologist, clay, occurring in a large mass, is as much a 'rock' as is granite, or limestone, or coal, or sandstone, or sand. In parts of Worcestershire and Herefordshire a red sandstone, and in Cheshire and Warwickshire red or yellow sandstones and marls, support the soils and subsoils. In North Wales the subsoil often rests upon slaty rocks, and in many districts of Cornwall and Devon granite is the underlying rock.

For some parts of Britain maps of the 'surface geology' are also published by the Geological Survey. These show the distribution of soils and other surface deposits.

It is difficult at first to grasp the fact that **soils are formed from rocks,** such as the limestones and sandstones which are used for building purposes or for road-mending, and such also as slaty rocks and granites. If these rocks could be kept out of the reach of water and air they would undergo little or no change. When a limestone or sandstone quarry is opened, the rock as it is hewn out comes into the light in the same condition in which it has probably been for thousands of years. As time progresses the face of the quarry loses its fresh appearance, and it is apparent that some change is taking place on the surface of the stone. This change is due to the action of air and moisture.

The process whereby hard rock masses are naturally broken up is termed **disintegration.** The agents of

disintegration are deserving of study, because they are quite as actively engaged in the soils which it is the province of the farmer and gardener to till, as in promoting the decay of the rocks from which the soils are derived.

Water is the chief agent of disintegration, and it may act in two ways, physically and chemically. Its physical effect is seen in the action of ice and running water, and particularly in the conversion of water into ice, that is, in the process of freezing. Nearly every known substance diminishes in volume as its temperature is lowered. This is true of water as it cools down from the boiling point (212° F.) till it approaches the freezing point (32° F.). At about 40° F., however, it begins to expand again, and at the moment of conversion into ice (at 32° F.) it undergoes a marked increase in volume, so much so that 9 cubic inches of water will make about 10 cubic inches of ice. The force of this expansion is well-nigh irresistible, and the fabric of a rock is necessarily weakened by the freezing of the moisture with which the rock mass is permeated, any small particles which may thus get broken off being easily carried away in the water that trickles from the rock.

On soils that are left rough and bare through the winter the effects of the alternate freezing and thawing of the soil moisture are readily noticeable. The expansion of the water in the act of freezing pushes apart the constituent particles of the soil, and by the end of winter the soil may have crumbled into that fine state of subdivision often described as 'mellow.'

In districts where chalk is plentiful, lumps of this white rock are sometimes put on the land in the autumn. By the beginning of spring each hard piece of chalk will have crumbled down into a heap of powder, a result that is very largely due to the disruptive effects of frost.

At one time in one part of the globe, and at another time in another, moving ice, in the form of glaciers, has helped much in reducing hard rocks to a finer condition. As a glacier flows along the surface of the land it scratches and grooves and crushes the underlying

rock. It also, in its course, carries with it the rubbish (*detritus*) which results from the destruction of the rocks, and may transport this rubbish to a considerable distance, where it may help to form a soil far from the place of its origin. Such *transported* or *erratic* soils (Lat. *erro*, I wander) are common in many parts of Britain. In the counties of Norfolk and Suffolk, for example, the rock of the district is largely covered by soils the mineral matter of which was thus transported by glaciers. The Till, or Boulder Clay, of the North of England, and of Scotland, had a similar glacial origin.

The physical effect of **running water** is two-fold. It *denudes* or lays bare the surface along which it flows, and it *carries away* and deposits elsewhere the material which is removed from the rocks. Most of our river valleys have been scooped out by the action of running water. An inspection of the sediment which gathers at roadsides in a heavy shower of rain will serve to show how water can make runnels or channels for itself, and the stone beneath the village pump usually affords some signs of the wearing effect of running water.

Certain fertile soils which are spread out near the mouths of rivers have been accumulated almost entirely by the action of running water, and they are fittingly called *alluvial* soils (Lat. *alluvio*, an overflowing). They are made up of the material, derived from the wear and tear of rocks, which is brought down in the river water. Such alluvial soils are found bordering the estuaries of the Thames, the Severn, and other rivers. Even the clearest river water contains sediment, as may be seen by allowing a tumbler of such water to stand for a few hours, when the bottom of the tumbler becomes covered with a fine deposit. This sediment is held in the river water *in suspension*, as it is termed, not in solution.

Besides the mechanical action of water upon rocks and rocky substances, there is also its chemical action to be considered. Some constituents of certain rocks are more or less soluble in pure water—rock-salt, gypsum, and silica, for example. The solvent power of rain water is, however, much increased by a property which is conferred upon it in falling through the air.

The atmosphere* contains a very small proportion of carbonic acid gas, or carbon dioxide, as it is also called. This is the same gas as is formed when charcoal (a nearly pure form of carbon) is burnt in the air. Rain in falling to the earth dissolves some of the carbonic acid gas of the atmosphere, and water thus charged with carbonic acid is capable of dissolving certain substances which are insoluble in pure water. The most important substance thus dissolved out of the rocks is **carbonate of lime,** a material of which limestone, chalk, and marble are chiefly composed.

Silica, of which the purest natural form is seen in rock crystal (quartz), and a less pure form in common sand, is slightly soluble in pure water, and more so in water containing carbonic acid. Various minerals (felspar, mica, etc.) found in granite and other igneous rocks are likewise more soluble in water containing carbonic acid.

Igneous rocks, to which reference has just been made, are those that have cooled down from a molten condition to the form in which we now see them; granite and basalt are examples, as are also the lava and pumice poured out from volcanoes like Vesuvius and Hecla. **Aqueous rocks** are those which have been deposited under water; such are clays, most sandstones, limestones, and deposits of rock-salt. Aqueous rocks are usually stratified, that is, arranged in beds or layers; igneous rocks are not. Aqueous rocks often enclose remains of animals and plants (fossils); igneous rocks never do. Aqueous rocks are usually granular in texture; igneous rocks are commonly crystalline. The rocks exposed at the surface of the earth are mostly of aqueous origin.

The oxygen of the air co-operates with carbon dioxide in promoting the decay of rocks, upon the constituents of which it may act either in the form of

---

* Atmospheric air is a mixture (not a compound) of nitrogen gas and oxygen gas, the former being four times as abundant as the latter. In addition, the atmosphere contains about four volumes of carbonic acid gas in 10,000 volumes of air (equal to 400 volumes per million), together with a varying quantity of water vapour, about one part per million of ammonia gas, and small quantities of chlorine and other constituents.

gas or as a solution in water. The process is one of oxidation, and the oxides formed are liable to be carried away dissolved in water. Thus the disintegration of rocks is further effected, and the formation of soils promoted.

Soils, then, are formed from rocks, and the subsoil may be regarded as something between the two. It

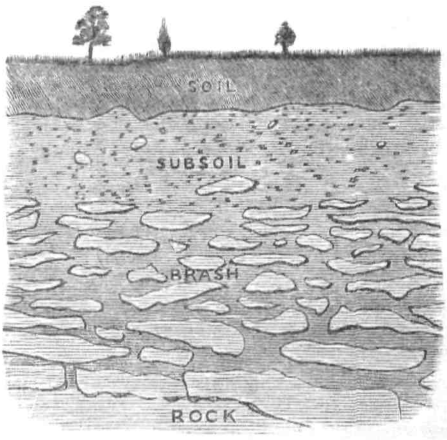


FIG. 1.—Diagram illustrating the formation of a sedentary soil on the Oolitic limestone of the Cotswold Hills, Gloucestershire.

differs from the rock, but the changes it has experienced have not gone far enough for the production of true soil. A convenient term to include the whole of the changes which have been described, and which result in the **conversion of rock into soil,** is **weathering.**

Some soils are directly produced from the rock that lies beneath them, as is the case with the thin soil resting upon the chalk of the Wiltshire Downs or the oolitic strata of the Cotswold Hills. Such soils (fig. 1) are described as **local, sedentary,** or **indigenous.**

In other cases, soils bear no relationship to the underlying rock. Examples are afforded by the alluvial soils around the Wash, and in Holderness, and by the Boulder

Clay of many northern counties. These soils, as has already been stated (p. 6) are termed **erratic** or **transported.**

The weathering agents, whereby rocks are converted into soils, do not cease to act when at length a soil is formed. On account of the usually loose condition of soils, they are, indeed, more susceptible than rocks to the influence of frost, rain, and snow, of running water, and of oxygen and carbonic dioxide: for these agents more easily gain access to the interstices of the soil than to those of the rock. Other agents, moreover—living agents in the form of plants and animals—work upon the fabric of the soil. In the case of cultivated soils, crops grow and are removed, whilst their roots remain in the soil to increase the store of organic matter or humus. This, in the course of its decay, enriches the air in the soil with carbon dioxide, which increases the solvent power of soil water. Under the influence of the air and water in the soil, the fragments of rocky matter which it contains are broken up, and added to the store of soil proper.

Hence the **constituent parts of a soil are ever changing.** Crops are continually carrying away certain ingredients of the soil, whilst the 'fine earth' of the soil is as constantly being added to by the decomposition or decay of the stony fragments which the soil contains. In addition, the **rain** which falls upon the land brings with it from the atmosphere certain substances which are of much importance in cultivated soils.

Of the animals which dwell in the soil, none approach the **earthworm** in the magnitude of their effects. Earthworms feed upon the organic matter in the soil, and in order to get sufficient food they have to pass large quantities of earth through their bodies. This earth is ejected in the form of castings, which may often be seen as little mounds on the surface, near the entrance of the burrow. Through the burrows of earthworms, air and water can penetrate more freely into the soil, and the work of decomposition progresses more rapidly. It has been calculated that an acre of ordinary agricultural land contains about 50,000 earthworms. The effect of their

combined labours in reducing the soil to a finer condition is great, whilst they also enrich the surface soil in nitrogen. In old pastures the production of a close, compact greensward is largely due to the fine earth which is brought to the surface by earthworms, to be afterwards crumbled down and levelled by the effect of sun and wind.

CHAPTER II.

COMPOSITION AND CLASSIFICATION OF SOILS

THE solid substances found in soils consist either of mineral (inorganic) matter or of organic matter. The **mineral matter** is derived from the decay of rocks. The **organic matter** (humus) arises from the decay of animal and vegetable substances. The most abundant mineral ingredients of soils are sand and clay. To a less extent, lime also, generally as carbonate of lime, is often present.

What **sand** is may best be learnt by examining the sand on the sea-shore, or in a sand-pit, or in a heap of sand intended to be mixed with lime for making mortar. In many country districts fine sand can be scraped together on the roadside, after a heavy storm of rain. It consists of a number of small hard clean particles of stone which, looked at through a magnifying glass, are usually found to be rounded like the stones or pebbles in gravel. Sand is, in fact, a very fine sort of gravel, and the small particles of the latter which pass through a sieve can afterwards be shovelled up as sand.

When sand is put into a bowl and water poured upon it, the liquid at once sinks into the sand. If the bowl be turned upside down upon the ground the water will drain from it, and the heap soon becomes dry. Particles of sand will not adhere to each other, and if moist sand is made into a ball in the hands, it will fall to fragments after the pressure ceases. Hence it is that sand is easily carried by the wind, and on some sea-coasts

this drifting of loose sand takes place to a serious extent.

A soil consisting entirely of sand would be useless to the cultivator, for he could grow nothing upon it. Plants would be unable to get sufficient hold for their roots. Besides this they would pine away for lack of moisture, because all the rain that fell upon such a soil would trickle through and leave it dry. The physical properties of sand, therefore, are such that a soil of pure sand would not be of any value.

Sand is equally deficient in respect of its chemical properties. It is generally composed of silica (SiO_2), and can offer to plants but little that may serve them as food. A *micaceous* sand, however, contains fragments or spangles of the glittering mineral mica, which, when decomposed, is capable of yielding potash, lime, iron, etc., some of which may be used by plants as food. Sand may also contain grains of other minerals (felspar, hornblende, etc.) from which plant food may be derived.

Although ordinary sand, by itself, has no physical or chemical qualities which can commend it to the cultivator, yet as a *constituent* of soils it confers upon them two important physical properties. It tends to make them light and open, and therefore permeable to moisture, air, and warmth. In addition, its stony particles become warm under the rays of the sun, and so the temperature of the soil is raised.

Clay is made up of exceedingly minute particles which readily adhere to each other, so that clay, when moist, can be moulded or kneaded by the hand into any desired shape. Hence its use in making bricks, tiles, drain-pipes, and pottery. When water falls upon a surface of clay it accumulates in puddles, and water that is lodged in the interstices of clay has very little tendency to drain away. Clay, therefore, is described as impermeable to water.

The chemical composition of clay is less simple than that of ordinary sand. The latter is made up wholly of silica. Pure clay contains silica combined with another substance called alumina. Like silica, alumina also is an oxide, being composed of oxygen combined with a

silvery-looking metal, aluminium, which has a number of useful applications in the arts. Water enters into the composition of all natural clays, and these are accordingly described by the chemist as hydrated silicates of alumina, a name that sufficiently indicates the presence of water, silica, and alumina, 'hydrated' being derived from the Greek word for water.

From a chemical point of view, pure clay would be as useless as pure sand as a source of plant food. But clays are always more or less impure, and the impurities present usually contain elements, such as potassium, magnesium, calcium, and iron, which play an important part in the nutrition of plants. The physical properties of clay are, in many respects, the reverse of those of sand. Sand is loose and non-cohesive, clay is firm, plastic, and tenacious; sand rapidly loses moisture, clay is very retentive of it; sand easily becomes hot and dry, whereas clay remains cool, and is well able to resist a drought.

It appears, then, that a soil consisting entirely of clay would be very firm, cold, and damp, and if exposed to much rain the surface would become muddy, owing to the moisture not draining away. As one of the constituents of the soil, however, clay is found to possess many valuable properties. Thus, it holds the oxygen of the air; retains water, thereby keeping the soil moist; gives tenacity to the soil; absorbs and retains the useful products resulting from the decomposition of manures, such as ammonia, potash, lime, and phosphoric acid; and is rich in useful substances (alkalies) adapted to supply plants with food.

Most soils contain **lime** (generally as carbonate of lime), though this substance is rarely present in large proportion. If some powdered chalk, or Bath freestone, or broken marble—all of which are composed of carbonate of lime—is put in a tumbler, and a weak solution of hydrochloric acid is poured upon it, the union of the carbonic acid gas with the lime will be broken, and the gas will escape in bubbles.

If a soil contains lime in any appreciable quantity its presence can be detected in the manner just indicated.

Take a small portion of soil which has been dried and rub it down to a powder, then pour a few drops of weak hydrochloric acid upon it. If carbonate of lime is present, effervescence will result.

It is necessary to distinguish between **lime** and **limestone,** because unfortunately the term 'lime' is popularly made to do duty for both. Limestone, as has been said, consists of lime combined with carbonic acid gas; it is a carbonate of lime, or, to use strictly chemical nomenclature, calcium carbonate. Lime can be obtained from limestone by burning the latter in a limekiln wherein the heat is sufficient to drive the carbonic acid gas away from its combination with the lime. The whitish substance (quicklime), left behind crumbles when touched. If water is poured upon it the liquid is greedily absorbed, there being a marked rise in temperature, and the resulting mass is known as hydrated lime, or slaked lime, or slack lime. If quicklime—also called caustic lime—be exposed to the air, it will, besides absorbing water, re-unite with carbonic acid gas, and gradually revert to the form of carbonate of lime or limestone. Pure lime never occurs naturally.

When it is said that a farmer is 'liming' his land, it is not always certain whether it is meant that he is giving it a dressing of lime—that is, quicklime—or of carbonate of lime (chalk, or ground limestone).

As a constituent of soils, lime, if sufficiently pulverised, has useful agricultural properties. On account of its reaction with acids it aids the decomposition of organic manures, such as farmyard manure, and promotes the formation of nitrates in the soil. Most limestones are more or less impure, owing to the presence of phosphates or sulphates of lime, magnesia, etc., the elements of which are valuable as ingredients of plant food. Calcium carbonate renders clay soils more friable.

Humus consists chiefly of decaying vegetable matter in the soil, sometimes mixed with a greater or less proportion of animal substance. It has a dark brown or blackish colour. Well-rotted leaf-mould, so largely used by gardeners, is very rich in humus. The compounds produced by the decay of organic matter in the

soil contain a larger proportion of nitrogen to carbon than exists in living vegetation, the carbon of the humus being diminished owing to much of it going off in union with oxygen as carbon dioxide. It was formerly thought that humus was capable of serving directly as plant-food, but this has been proved to be not the case. Nevertheless, humus is of great value, because the final products of its decomposition—chiefly carbon dioxide, ammonia and water—are capable of ministering to the food requirements of growing plants. The quantity of humus usually present in cultivated soils ranges from 2 to 9 per cent., and, within these limits, the soil will be the richer, or the more fertile, the more humus it contains. It is possible, however, for a soil to contain too much decaying organic matter; this is the case with peaty soils and boggy moorlands.

Garden soils commonly contain more humus than ordinary agricultural soils. Sandy soils need to be enriched with humus, not only on account of its containing fertilizing ingredients, but equally for its moisture-holding capacity. Of the various constituents of soils none are equal to humus in the power of absorbing and retaining moisture; hence, a soil rich in humus is better able to withstand drought. In contrast with the free, open, sandy soils are the firm, dense, water-holding clay soils; in these, humus has a physical value on account of its property of loosening, and thereby opening and aërating, the soil. Consequently, the very growth of crops may improve the soil for future crops, because the crop-residue, in the form of roots and stubble, goes to increase the store of humus which the soil contains. Hence it is desirable in some cases to increase, and in others to judiciously regulate, the quantity of humus contained in the soil.

By the process of **green manuring**—that is, raising a crop of mustard, rape, or any other quick-growing plant, and ploughing it in green—the amount of organic matter in a soil can be speedily increased.

Classification of Soils.—Soils consisting almost exclusively of one constituent are rare and exceptional. Nearly all soils of the farm and garden will be found

to contain sand, clay, a little limestone, and some amount of humus. Inasmuch, however, as clay and sand are, in point of quantity, by far the leading ingredients of most soils, it has been found convenient to classify soils according to the percentages of clay and sand they contain.

Suppose, then, for the sake of simplicity, that a soil consists almost entirely of sand and clay. If, in such a case, the quantity of clay does not exceed 5 per cent. of the weight, a *sandy soil* is the result.

With from 5 to 10 per cent. of clay it is a *sandy loam.*

With from 10 to 20 per cent. of clay it is a *loamy soil.*

With from 20 to 30 per cent. of clay it becomes a *clay loam*, with from 30 to 40 per cent. of clay it is a *clay*, and with over 40 per cent. of clay a *strong* or *heavy clay.*

A *loam*, it will be noticed, is a soil consisting of a mixture of sand and clay. A *gravel loam* and a *chalk loam* are loams of which gravel and chalk respectively are noteworthy ingredients.

A *marl* is a clayey soil containing from 5 to 20 per cent. of carbonate of lime. Should the limestone present exceed 20 per cent. of the total weight a *calcareous soil* (Lat. *calx*, limestone; *arena*, sand) is the result. A sandy soil containing some amount of carbonate of lime is called *chalky sand.*

For nearly all purposes loams make the most suitable soils. If a soil happens to be excessively sandy, or clayey, or calcareous, or peaty, it will be improved in character in proportion as it is brought to resemble a good medium loam. The object of the cultivator is, as far as possible, to bring it into such a condition.

Experience proves that a soil is best adapted for purposes of cultivation when it contains of—

Sand (siliceous and calcareous) ...	from	50	to	70	per cent.
Clay	„	20	„	30	„ „
Carbonate of lime	„	5	„	10	„ „
Humus	„	5	„	10	„ „

It thus contains enough sand to make it warm, and pervious to air and moisture; enough clay to render it moist, tenacious, and conservative of manures; enough

limestone to furnish calcareous material and to decompose organic matter; and, lastly, sufficient humus to assist in supplying the food requirements of plants, and to aid in maintaining the carbon dioxide in the interstitial air of the soil. The reason that alluvial soils are generally so fertile is the mixed mineral character they possess, owing to their having been usually derived from the disintegration of various kinds of rocks, and not of one kind only. Such a soil as that indicated in the above table is, however, the exception rather than the rule in nature, most soils being characterized by too great an excess of one or more of the ingredients.

Various **agricultural terms** are applied to soils. A sandy soil is described as light, and sandy and loamy soils are spoken of as open and free-working. Friable soils are readily crumbled between the thumb and fingers. A clay soil is described as heavy because it is sticky or tenacious; it may also be termed stiff or stubborn. As a matter of fact, however, a cubic foot of sand weighs more than a cubic foot of clay, the terms 'light' and 'heavy' referring to consistency rather than to density. A 'mellow' soil is one which, by natural or artificial means, has been reduced to a fine state of subdivision. A 'hungry' soil is one which is greedy of manure and of water, with little power of retaining either! a poor sandy soil is an example. A 'cold' soil contains an excess of clay or of humus, both of which retain water. A 'shallow' or 'thin' soil is one in which the distance from the surface to the subsoil is but little; on the Chalk Downs some of the soils are so shallow that they cannot be ploughed deeper than 3 inches. To go below this would bring up so much carbonate of lime (chalk) that it would exercise an injurious effect for years. A 'deep' soil, such as many clays, is of considerable thickness.

Mechanical Analysis of Soils.—A given soil consists of fragments and particles of different size, the sorting out of which is effected by mechanical analysis. The sample to be examined is first dried, the weight of moisture lost being noted, and then shaken through a sieve with round holes 3 mm. in diameter. In this way

the 'stones' are separated from the 'fine earth.' The latter is then treated successively with dilute hydrochloric acid and ammonia, for the purpose of removing the carbonates and humates that help to bind its particles together. The fine earth is then air-dried, after which fine gravel, coarse sand, and fine sand are separated by means of sieves with holes of suitable dimensions. The very finely divided material (silt and clay) that remains is then sorted into size constituents by means of water. This is sometimes done by stirring up the soil in a full cylinder of water and afterwards allowing it to settle. The coarsest particles are deposited first and its finest ones last. More accurate results are obtained when water currents of known force are used to wash out particles of corresponding size.

The following will serve as an example of mechanical analyses:—

TABLE I.—*Soils from* CHAPEL CLOSE, ROYAL AGRICULTURAL COLLEGE, CIRENCESTER (M. KERSHAW).

	Soil A.	Soil B.	Soil C.
	per cent.	per cent.	per cent.
Stones, diam. over 10 mm.	·4	2·2	·4
Small stones, diam. over 3 mm. ...	1·5	1·7	·15
Loss on treatment with acid	37·6	18·9	11·6
Fine gravel (3 mm.— 1 mm.) ...	1·53	·52	·95
Coarse sand (1 mm.— ·2 mm.) ...	1·62	1·58	1·35
Fine sand (·2 mm.— ·04 mm) ...	5·69	9·92	15·17
Silt (·04 mm.— ·01 mm.) ...	13·48	11·99	17·88
Fine silt (·01 mm.—·002 mm.) ...	15·36	18·64	21·93
Clay (below ·002 mm.) ..	13·89	22·24	21·34
Moisture	9·96	10·60	9·49
Organic matter, etc., lost on heating	12·73	14·56	11·40
Dissolved matter ... ... (carbonates and humates) mostly calcium carbonate	27·64	8·30	2·11

The stones were nearly all limestone (calcium carbonate).

Chemical Analysis of Soils.—Of the chemical ingredients of soils, silica, alumina, and lime have already been noticed. Others, usually present, are potash, soda, magnesia, oxide of iron, phosphoric

acid, sulphuric acid, and chlorine. With the exception of chlorine these are all oxides, that is, compounds formed by the union of oxygen with some other element, though, in the case of the two acids named, water also enters into the composition. Potash, soda, magnesia, and oxide of iron are compounds of oxygen with the metals potassium, sodium, magnesium, and iron respectively. Phosphoric acid and sulphuric acid contain, as their names imply, the non-metallic elements, phosphorus and sulphur respectively, combined with hydrogen and oxygen. The substances which have been named do not usually exist free in the soil—no soils contain potash, soda, lime, or magnesia, as such, though many include free oxide of iron. The oxides of the metals (*bases* as they are termed) exist in soils in combination with the acids, forming *salts.** All clays contain silicate of alumina, and frequently silicate of potash. Phosphates, sulphates, and carbonates of lime, and of magnesia, occur naturally in many soils. Oxide of iron, though not present in quantity, is of interest in that the **colours of soils** are more frequently due to this ingredient than to any other. Red and yellow sands and clays owe their colour to the presence of similarly coloured oxides of iron. Oxygen combines with iron in several different proportions, and the change in colour of a subsoil from a bright yellow to a rusty brown may be due to the bright yellow oxide of iron becoming more thoroughly oxidized when the subsoil is exposed to the air at the surface.

Availability of Plant Foods.—An ordinary chemical analysis of a soil enumerates various substances known to be essential as plant food, but does not state whether these are immediately available for use. The roots of plants can only absorb compounds in solution, the feebly acid sap and dissolved carbon dioxide constantly diffusing out and thus helping to prepare such solutions. By extracting a soil with a 1 per cent. solution of citric acid the natural action of roots is, so to speak, imitated,

* Acids whose names end in *ic* form salts whose names *usually* end in *ate*; thus, sulphuric acid forms sulphates; nitric acid, nitrates.

the substances thus dissolved out representing the plant food which can at once be drawn upon, and also serving as a guide to manurial treatment. The citric acid method, however, is practically only a guide to the amounts of available phosphoric acid and potash present.

Of the various substances required by crops to sustain their growth, there are four of which the available supply in the soil is liable to run short, so that the deficiency has to be made good by the cultivator. These are **nitrogen, phosphoric acid, potash,** and **lime.** The latter three, as they occur naturally in the soil, belong to the *mineral ingredients.* Nitrogen, on the other hand, is derived from the decay of *organic matter* in the soil and to some extent from the atmosphere, in addition to which small but variable quantities are brought down in rain.

In most ordinary soils, **sand, clay,** and **humus** make up as much as nine-tenths of the whole, the actual ingredients upon which plants feed being comparatively small in amount (see Analyses, p. 20). The sand, clay, and humus, which constitute the bulk of the soil, furnish the staple or fabric in which the roots search for food. They contain varying amounts of material which, later on, may be converted into plant food ready for absorption, but are for the time being 'dormant' or 'unavailable.' The quantity of soluble matter available, even in rich soils, is never abundant at any one time, and to add very large amounts of such matter would defeat the end in view, for roots can only absorb *weak* solutions. The object of the cultivator in his treatment of the soil—by tilling, manuring, fallowing—is to provide a succession of **active or available plant-food,** so that as the nitrogen, phosphorus, potash, lime, and other matters existing in the soluble form are used up, fresh supplies may be ready to take their place. If the soil should run short of any ingredient of plant-food it is said to be **exhausted** of that substance, and crops cannot be grown till it is replaced in sufficient quantity. Moreover, an excess of one substance will not make good the deficiency of another; if a soil contains no potash an abundance of lime will not help it, and, similarly,

though a soil may be rich in nitrogen it will yet be incapable of growing crops if it has no phosphorus.

A good illustration of the **difference between soluble and insoluble plant-food** is afforded by nitrogen. Organic nitrogen, as it exists in farmyard manure, is insoluble in water, and therefore the plant cannot directly make use of it. The same nitrogen, after the process of nitrification, takes the form of a nitrate—nitrate of lime usually—which is soluble, and, dissolved in water, can be taken up by the plant.

The following **analyses of soils** have been specially selected, and are presented here together, as illustrative of the variations in the composition of soils, which is the subject discussed in this chapter. Respecting the four ingredients just referred to, it is seen that nitrogen is at its highest (2·47 per cent.) in the peaty soil, and at its lowest (0·12 per cent.) in the sandy soil. Of phosphoric acid, the percentages range from 0·16 in the clay soil to 0·10 in the sandy soil. Potash is at its highest (0·76 per cent.) in the clay soil, whilst lime is most abundant in the chalk soil and very deficient in the sandy soil. The student will notice the small percentages of nitrogen, phosphoric acid, and potash which are usually present in cultivated soils. He will also observe the high proportions of insoluble silicates and sand—amounting to four-fifths or more of the whole—which enter into the composition of clays, loams, and sandy soils.

TABLE II.—*Composition of a* SANDY SOIL.*
Sample 9 inches deep.

[1] Organic matter and loss on heating	2·82
Oxide of iron	·92
Alumina	·88
Lime	·18
Magnesia	·12
Potash	·07
Soda	·06
Phosphoric acid	·10
Sulphuric acid	·01
Insoluble siliceous matter	94·84
	100·00
[1] Containing nitrogen...	·12
equal to ammonia	·15

TABLE III.—*Composition of a* CLAY SOIL.*
Sample 9 inches deep.

[1] Organic matter and loss on heating	7·21
Oxide of iron	5·77
Alumina	4·45
Carbonate of lime	2·26
Magnesia	·79
Potash	·76
Soda	·06
Phosphoric acid	·16
Sulphuric acid	·10
Insoluble silicates and sand	78·44
	100·00
[1] Containing nitrogen	·16
equal to ammonia	·19

TABLE IV.—*Composition of a* LOAM SOIL.†
Sample 9 inches deep.

[1] Organic matter and loss on heating	5·07
Oxide of iron	3·63
Alumina	3·51
Carbonate of lime	1·48
Sulphate of lime	·34
Magnesia	·42
Potash	·30
Soda	·01
Phosphoric acid	·10
Insoluble silicates and sand	85·14
	100·00
[1] Containing nitrogen	·19
equal to ammonia	·23

TABLE V.—*Composition of a* CHALK SOIL.‡
Sample 6 inches deep.

[1] Organic matter and loss on heating	3·13
Oxide of iron	1·52
Alumina	1·63
Carbonate of lime	28·77
Sulphate of lime	·18
Magnesia	·36
Potash	·18
Soda	·11
Phosphoric acid	·15
Insoluble silicates and sand	63·97
	100·00
[1] Containing nitrogen	·18
equal to ammonia	·21

TABLE VI.—*Composition of a* PEATY SOIL.*
Sample 9 inches deep.

[1] Organic matter and loss on heating	64·66
Oxide of iron and alumina	13·96
Carbonate of lime	1·80
Potash, soda, magnesia, etc....	·98
Insoluble silicates and sand...	18·60
	100·00
[1] Containing nitrogen	2·47
equal to ammonia	2·99

* From Exeter, Devon.

CHAPTER III.

PHYSICAL PROPERTIES OF SOILS

Structure of Soil.—A soil consists, as we have seen (p. 17), of particles of various size and kind. The interstices between these particles collectively form what is known as the 'pore space,' which is greatest in clays (up to 50 per cent. of volume), and least in some of the coarser sands (25 to 30 per cent.). The density of the materials making up soils (true density) is obviously greater than the density (apparent density) of the soils themselves when dry, because the latter possess a larger or smaller pore space. The apparent density of a dry soil is obtained by dividing a given weight by its volume. Owing to the large pore space in clay soils these are really lighter than sandy soils with a smaller pore space, as will be seen from the following table (A. D. Hall):—

TABLE VII.—APPARENT DENSITY AND WEIGHT OF SOILS.

Kind of Soil.	Apparent Density.	Weight per cubic foot.	Lbs. per acre of a layer 9 inches thick.
Heavy clay	1·062	66·4	2,150,000
Sandy clay	1·279	80	2,600,000
Sandy clay subsoil ...	1·18	73·7	2,360,000
Light loam	1·222	76·4	2,480,000
Light loam subsoil ...	1·144	71·5	2,320,000
Sandy loam	1·225	76·7	2,490,000
Sandy peat	0·782	49	1,580,000
Light sand	1·266	79·2	2.560.000

Since the roots of plants derive their food from the thin films of moisture clinging to the soil particles, it is obvious that the total surface presented by these in different cases is a matter of practical as well as theoretical interest, especially as it is also related to the power of retaining water and of taking up certain substances from solutions. The following table embodies the results of calculations made to determine the surfaces offered by soils of different kinds.

TABLE VIII.—PORE SPACES AND SURFACES OF SOILS.

Kind of Soil.	Pore space, per cent.	Area of Surface in square feet, per cubic foot of Soil.
Finest clay	52·9	173,700
Finest clay soil	48	110,500
Loamy clay soil ...	49·2	70,500
Loam	44·1	46,500
Sandy loam	38·8	36,900
Sandy soil	32·5	11,000

"As a rough figure to remember, the surface of the particles in one cubic foot of an ordinary light loam may be taken as about an acre; this will increase as the soil approaches more and more to clay, and diminish as the soil becomes increasingly sandy." (A. D. Hall.)

Air of the Soil.—The pore space in an ordinary soil, together with worm burrows and other relatively large cavities that may be present, is more or less full of air. The oxygen required by the roots of plants to enable them to breathe is derived from this air, and thorough ventilation of the soil is absolutely necessary if crops are to flourish. The air in the soil also plays an important part in the complex changes that are incessantly going on, largely as the result of the activity of microscopic organisms, and by which the store of available plant food is continually being increased. The object of drainage is to increase the volume of soil through which air can freely circulate.

Water of the Soil.—A large proportion of the water which a soil is capable of holding may be termed 'free,'

i.e., it drains away with greater or less readiness. But after its removal a great deal of water still remains, clinging to the particles of soil by means of 'surface tension.' The meaning of this term is difficult to understand without a special knowledge of physics, but it will suffice for our present purpose to state that at the surface of a layer of water, where it is in contact with air, the molecules of water are drawn inwards by the attraction of deeper water molecules more powerfully than they are drawn outwards by the attraction of the air. It follows from this that the film of moisture adhering to a particle of soil may be compared to an elastic membrane on the stretch, and therefore trying to contract inwards. The water thus tightly held by the soil is of primary importance to plants, as it constitutes the plant food absorbed by the roots.

Soils differ very much from one another as regards their capacity for taking up water. This is greater in proportion to the amount of clay and humus present. The most favourable or 'optimum' amount for plant growth is from 40 to 50 per cent. of the total capacity.

Soils may suffer as much from containing too much water as from possessing too little. By draining, on the one hand, and by suitable tillage, on the other, it is possible for the cultivator to exercise some control over the moisture in the soil. Crops, especially in droughty weather, draw largely upon the stores of moisture within the soil. To such an extent is this the case that cropped land generally gives up more moisture than it would if left in bare fallow. In the case of a crop of barley grown at Rothamsted there was removed from the soil more water [equivalent to 9 inches of rainfall] than had evaporated in the same time from an adjoining bare fallow. The powerful action of a crop in robbing a soil of its moisture is mainly due to the rapidity with which water evaporates during daylight from the surface of the leaves. A deep-rooted crop, like sainfoin or lucerne, may be more effective in drying the soil than a shallow-rooted crop, such as barley or oats.

The water which evaporates from leaves goes off as pure water vapour, the substances dissolved in the water when it leaves the soil remaining behind in the plant, and aiding in its nutrition. Experiments have led to the conclusion that from 250 to 300 lb. of water are evaporated from leaves for 1 lb. of dry matter added to the plant.

Sometimes the evaporation of moisture from the leaves goes on more rapidly than the roots take up fresh supplies from the soil. This state of things may often be seen in a mangel field on a hot sunny afternoon in July or August, when the leaves are all limp and drooping. As evening approaches, and the evaporative power of the sun's heat is lessened, the supply of water from the soil again equals the demand of the leaves, and the latter resume their crisp character, because their tissues become turgid with water.

The maintenance of a suitable degree of moisture in the soil depends largely upon its physical condition, and especially upon its capillarity.

No physical property is more familiar than that of **capillarity**, or capillary attraction. When a lump of sugar is held with one corner dipping in a cup of coffee, the brown liquid quickly suffuses the whole lump. When a fresh wick is allowed to dip into the oil-reservoir of a lamp, the oil speedily travels up the fabric. These are instances of capillarity, and the phenomenon is dependent upon the presence of innumerable very fine tubes (Lat. *capillus*, a hair). As the internal diameter of these narrow tubes increases, so does the power of capillary attraction diminish. Myriads of such tubes exist in the soil; and the finer the soil the more delicate, and consequently the more efficient, do these tubes become. On the other hand, the coarser a soil, that is, the more inferior the **tilth**, the more do the delicate narrow tubes give place to others of wider bore.

However dry and parched a cultivated soil may happen to be, it is not necessary to dig very deeply before moist soil is reached. By digging to a greater depth, the **water table**, or line of water level at the place, will be penetrated; and it will be seen that from

the water-level upwards the earth is moist, though the actual soil may have lost all, or nearly all, its moisture. The fact that such a soil is not moist up to the surface is partly due to evaporation, though it is a question not so much of evaporation as of capillarity. The capillary tubes, having lost most of their moisture by evaporation, have crumbled into other more open tubes, too broad for the water to travel along, and hence the surface soil has been deprived of those myriads of minute invisible conduits which would have enabled it to continuously draw its supplies of moisture from the reservoir below. Had the surface soil been kept in a state of fine tilth—and this can be done by stirring it sufficiently frequently—the moisture would have travelled up from below to replace that which evaporated.

When rain falls upon the soil, some of it sinks down to replenish the stores below; but, during the period of active growth, and particularly in a droughty season, there is a movement of moisture from below upwards. This moisture replaces that lost at the surface by evaporation; and its direction is such that it tends to keep the soluble plant food where it is wanted, that is, about the roots of the plants. If enough water be poured into a saucer in which stands a flower-pot full of earth, the surface of this mould will at length become moist, the water having travelled upwards by capillarity.

But here another important point has to be considered. If all the capillary tubes are open to the surface, evaporation can proceed from them so freely that the underground store of moisture may be insufficient to supply the continuous demand. Hence, again, it is desirable to keep the surface soil, by frequent stirring, in such a state that the capillary tubes are broken, or interrupted, a little below the surface. In this case the mere superficial covering of mould acts as a **soil mulch**; and, like a layer of leaves, or grass, or farmyard manure, it protects the moisture beneath. Hence an occasional slight stirring of the superficial soil serves to conserve rather than to dissipate the underlying moisture, and such operations as hoeing and raking (harrowing) may be usefully resorted to even in very hot weather.

In cases where, from frequent ploughings at the same depth, what is called a 'plough pan' has formed, or where a layer of farmyard manure has accumulated beneath the soil, the overlying soil soon becomes dry, and speedily suffers from drought. The explanation, of course, is that the surface soil has been cut off from capillary continuity with the moisture-laden earth below, and there has been no upward current of moisture to replace that which has been lost by evaporation at the surface.

When land has been ploughed time after time, to the same depth, it is no unusual thing for a hard layer or **plough pan** to form. It opposes the passage of water, and the roots of plants are unable to penetrate it. The repeated sliding of the base of the plough at one depth, and the treading of horses and men along the furrow, are the cause of the consolidation to which the pan is due. It is necessary that all such hard or indurated pans should be broken, and this is effected either by the subsoil plough, the trench plough, or the steam cultivator. The subsoil plough breaks and stirs the subsoil without bringing any of it to the surface. The deeper-working trench plough acts more thoroughly, but at the risk of bringing up to the surface objectionable matter. The incorporation of subsoil with soil is a procedure to be adopted only with great caution.

Natural pans are formed by chemical agencies. On calcareous soils, or where lime has been freely used, this material may form a **lime pan** at a moderate depth from the surface. The changes are similar to those which take place when lime and sand harden in mortar. In soils containing an undue proportion of oxide of iron, this material is washed into the subsoil, and cakes the particles together into an **iron pan.** In the same way the links of an iron chain may be cemented into one piece by iron rust. **Peaty** or **moorland pans** occur in heath and bog soils, and may arise from the accumulation of salts of iron beneath the surface. The subsoil plough and, in the case of lime pans, the trench plough, must be set to work to reduce these obstructive layers,

burning the plants and analysing their ashes, which yield substances identical with some of the mineral matters of the soil, and different from anything which is contained in the air. The soil loses water, partly by direct evaporation from the surface into the air, but more especially through supplying that which the plant gives up by evaporation (transpiration) from the leaves. A still more serious loss is that which is effected through the medium of the water—**drainage water**—which flows away from the soil. Such water carries with it particles of soil—fine earth—in suspension, and it inflicts even a greater loss upon the soil by dissolving certain substances and carrying them away invisibly in solution. By analysing drainage waters, and comparing the results with analyses of the rain waters which fall upon the soil, it has been possible to arrive at many useful facts concerning the behaviour of soils towards substances which are of importance as sources of food to crops. It has been ascertained that some of these substances are easily 'washed out' of the soil, and are therefore commonly present in the drainage waters. Other useful substances, which are known to be present in the soil, are usually found in the drainage waters in only minute quantities; the soil exercises what is called a *retentive power* over these, since it retains or keeps hold of them.

The substances of agricultural interest which are most readily carried away in solution by drainage waters are sodium and calcium chlorides and nitrates, and, to a less degree, sodium and calcium sulphates. The most important of these are the **nitrates**—'nitrate of soda' and 'nitrate of lime,' as they are commonly termed.

On the other hand, most fertile soils possess a great **retentive power** for **ammonia, potash,** and **phosphoric acid**; consequently, salts of ammonia and potash, and phosphates generally, are rarely found in any quantity in drainage waters, except under exceptional conditions. It is the clayey part of the soil which exerts the retentive influence upon these soluble bodies, and, when rain falls upon the land, the effect of its solvent properties is to cause a more equable distribution of these substances, rather than to wash them out.

Experiments have shown that the expulsion of soluble salts from the soil takes place most freely when the percolation of moisture is the most rapid, so that a heavy rainfall, restricted to a few days, does far more harm in washing the soil, than would the same amount of rainfall spread over a month.

The richness of drainage waters in nitrates is, in the climate of England, greatest in early autumn, whilst it diminishes through the winter, and is least in spring. The summer is, nevertheless, the season when nitrates are most abundantly produced in the surface soil; but, as little drainage occurs in summer time, owing to the temperature encouraging a high rate of evaporation, the nitrates at that season accumulate in the soil. As the autumn advances, drainage becomes active, and the **washing out of the nitrates** commences; the first drainage is not, however, always the richest, because the nitrates are most abundant at the surface and must be displaced by rain, and allowed time for diffusion, before they can appear in quantity in the drainage water. Shallow soils are most quickly washed out, whilst deep soils, possessing a larger mass for the diffusion of the nitrates, part with them more slowly and uniformly.

At Rothamsted, Hertfordshire, experiments have been made to find out what quantity of nitrogen may be carried away in drainage waters. Three drain-gauges were sunk in bare soil, each occupying a surface area of $\frac{1}{1000}$ of an acre, but extending to depths of 20 inches, 40 inches, and 60 inches, respectively. All the water that drained through the gauges was collected, and the quantity of nitrogen contained in it was ascertained in the laboratory.

It was found that the annual amount of nitrogen in the form of nitrates removed in the drainage water was, on an average of four years (1877 to 1881), 45·51 lb., 36·32 lb., and 43·59 lb., respectively per acre from the three drain-gauges, the mean of all being 41·81 lb. per acre, which is the amount of nitrogen contained in 268 lb. of ordinary nitrate of soda. Supposing—and this is a fair and reasonable supposition—that the drainage water contained at the same time 0·5 part of nitrogen per

million in the form of organic nitrogen and ammonia, this gives a total of 43·77 lb. as the quantity of nitrogen removed in one year, from an acre of uncropped soil, in drainage water which amounted to 17·281 inches. Such a quantity of nitrogen is equal to that contained in an average crop of wheat or barley; its loss to the soil in the drainage water is thus a matter of grave importance. Though such loss may be, and probably is, considerably less in an ordinary agricultural fallow, occurring in rotation, than in the Rothamsted drain-gauge experiments, the loss must clearly be a very serious one whenever the season is wet.

It has been estimated that, upon the farm soil at Rothamsted, as much as 80 lb. of nitrogen, as nitric acid, is formed in an acre of land during a whole year's bare fallow. In the drainage experiments just referred to, the mean annual amount of nitrogen per acre, carried away in the drainage waters *over a period of thirteen years* was 37 lb.

By **bare fallow** is meant an interval between the crops upon a soil, during which space of time no crop is grown upon the land. It is a *period of rest.*

Bare fallow can only be thoroughly successful in a dry climate, in which case the active production of nitrates, which takes place in a fallow, will doubtless greatly increase the fertility of the soil for the succeeding crop. In a wet climate the practice of bare fallow must result in a rapid diminution of soil nitrogen; hence farmers have introduced what are called 'fallow crops' and 'catch crops,' the effect of which is to intercept the nitrogen which would otherwise be lost, and could only be replaced by the use of expensive manures. One method by which a crop will greatly diminish such loss has already been noticed, namely, by largely increasing the amount of evaporation from the leaves (transpiration), and thus diminishing the amount of drainage.

Besides the drainage waters from bare fallow land, those from variously manured soils cropped with wheat have also been collected and examined at Rothamsted. Wheat is a crop which, so far as is known, is entirely dependent for its nitrogen upon the nitrates in the soil.

The average results for three years show that an unmanured soil upon which wheat was grown yielded only 3·9 parts and 4·5 parts respectively of nitrogen, as nitric acid, per 1,000,000 parts of drainage water. On the other hand, a bare soil kept free from weeds afforded 10·7 parts of nitrogen, as nitric acid, in 1,000,000 parts of drainage water. So that there was about two and a half times as much nitrogen washed out from the bare soil as from the soil upon which the wheat was grown. The much lower proportion of nitrates in the drainage water of the wheat land was partly owing to the exhaustion of the nitrogen of the soil by growing successive crops of wheat without manure, but it was chiefly due to the fact that the crop made use of the nitrates which would otherwise have been lost in the drainage water. So great is the demand of the wheat crop for nitrates that, during the period of most active growth, and for some time after, no nitric acid, or the merest trace only, could be found in the drainage waters collected from several of the plots in the wheat field in which the experiment was made.

The sources of gain to the soil are to be sought in the land itself, in the atmosphere, in the residues of crops, and in the application of manures and of other dressings.

In the land itself a slow conversion of subsoil into soil is always in progress, owing to the natural agencies that have been described. In certain circumstances it is found desirable to hasten this change by ploughing deeply enough to break the subsoil. In the case of a local or indigenous soil every gradation may be seen (fig. 1) between the free-working surface earth at the top, and the hard unweathered bed-rock at various depths beneath. The soil itself is a transition stage between the rock, which is the parent of the soil, and the finely divided or soluble matter which is usually carried away in the waters that drain from the soil, or —in the case of dissolved matter—is exported from the farm in the form of crops.

The stones and other coarse fragments in the soil are continually undergoing reduction to smaller size, and adding thereby to the 'fine earth' or mould amongst

which the roots of plants can travel in search of food. Every change of temperature that affects the soil, every frost that disrupts its particles, every shower of rain that soaks into its interstices, and every current of air that blows across its surface—each does its work in reducing the soil to a finer mechanical condition. To these natural causes must be added the powerful **agents of disintegration** which man has at his command in the plough and other implements of tillage.

TABLE XI.—THE MAXIMUM, MINIMUM, AND MEAN AMOUNTS OF CERTAIN CONSTITUENTS IN SIXTY-NINE SAMPLES OF RAIN WATER IN PARTS PER MILLION.

	Total Solid Matter	Carbon in Organic Matter	Nitrogen as				Chlorine.	Hardness.
			Organic Matter	Ammonia	Nitrates and Nitrites	Total Nitrogen.		
Highest proportion ...	85·8	3·72	0·66	1·28	0·44	1·94	16·5	16·0
Lowest proportion ...	6·2	0·21	0·03	0·04	0·01	0·13	0·0	0·0
Mean, 69 samples ...	33·1	0·90	0·19	0·37	0·14[1]	0·70	3·1	4·7

[1] The mean of 34 samples.

Rain, as a source of gain to the soil, supplies on the one hand most of the water upon which our crops are dependent for their growth, and on the other hand it **carries down from the atmosphere** certain ingredients which, though small in relative quantity, yet represent a significant addition to the stores of fertility within the soil. As rain condenses, and falls through the air, it dissolves some of the gases which are present in the atmosphere. In rain-water, collected in the country, nitrogen and oxygen are the chief gases dissolved, together with a small quantity of carbonic acid and a still smaller amount of ammonia. The rain further contains certain solid substances gathered in the course of its descent. Some of these, as the chlorides, sulphates,

and nitrates of sodium, calcium, and ammonium, are dissolved by the rain; others, as particles of dust and soot, are merely mechanically held, and give to rain-water its usually dirty appearance. As a rule these various substances are present only in very minute quantities.

An example of what rain-water may actually contain is shown in Table XI., which affords information concerning the composition of rain-water collected at

TABLE XII.—THE MAXIMUM, MINIMUM, AND MEAN AMOUNTS OF CERTAIN CONSTITUENTS IN SEVEN SAMPLES OF DEW AND HOAR-FROST, IN PARTS PER MILLION.

	Total Solid Matter	Carbon in Organic Matter	Nitrogen as				Chlorine	Hardness.
			Organic Matter	Ammonia	Nitrates and Nitrites	Total Nitrogen		
Highest proportion ...	80·0	4·50	1·96	2·31	0·50	4·55	8·0	25·0
Lowest proportion ...	26·4	1·95	0·26	1·07	0·28	1·66	3·5	13·0
Mean, 7 samples ...	48·7	2·64	0·76	1·63	0·40[1]	2·79	5·3	19·0

[1] The mean of 4 analyses.

Rothamsted. It indicates that nitrogen may occur in rain in the forms of nitrates, nitrites, ammonia, and organic matter. The carbon and nitrogen in the organic matter represent the soluble matter extracted by the rain from the organic dust with which it has come in contact in the atmosphere, or on the surface of the collecting vessels. The mean proportion of nitrogen to carbon is about 1 : 5 (0·19 to 0·90), so that the organic matter brought down in rain is of a decidedly nitrogenous character. The chlorine of rain-water is due to the presence of common salt. It will be seen that the total solid matter (33·1 parts) dissolved in rain-water is considerably greater than the sum (5·4 parts) of the

constituents which are specified in the table; the remaining matter is made up partly of sulphates, which form a large ingredient of rain-water.

Inasmuch as **dew** and **hoar-frost** are also sources of soil-moisture, the composition of several samples, likewise collected at Rothamsted, is given in Table XII. By comparing the figures of this table with those in Table XI. it will be learnt that these small deposits, condensed from the lower layer of the atmosphere, contain on an average three or four times the amount of organic carbon, organic nitrogen, ammonia, and nitric

TABLE XIII.—AVERAGE COMPOSITION OF SAMPLES OF RAIN FROM VARIOUS DISTRICTS OF ENGLAND AND SCOTLAND, IN PARTS PER MILLION.

	Nitrogen as		Chlorine.	Sulphuric Acid.
	Ammonia.	Nitric Acid.		
England, country places, inland...	0·88	0·19	3·88	5·52
" towns	4·25	0·22	8·46	34·27
Scotland, country places, sea coast	0·61	0·11	12·24	5·64
" " " inland ...	0·44	0·08	3·28	2·06
" towns	3·15	0·30	5·70	16·50
" Glasgow	7·49	0·63	8·72	70·19

acid found in the rain-water. The total quantity of solid matter, and the amount of chlorides, are also larger, but the difference is much smaller than in the case of the other ingredients. The mean proportion of organic nitrogen to carbon is 1 : 3½, as compared with about 1 : 5 in the rain-water.

The composition of rain-water varies, however, very considerably according to the locality in which it is collected, as may be learnt from a study of Table XIII. The rain of towns exhibits a large increase both in ammonia and sulphuric acid, and a smaller, though a considerable, increase in chlorides and nitrates. Chlorides are most abundant in the rain collected at the sea-coast. Rain collected at Valentia, on the west coast of Ireland, yielded as much as 47·35 parts of chlorine per million.

Independently of the carbonic acid gas which rain dissolves in its passage through the air (p. 34), nitrogen is by far the most valuable addition that rain makes to the soil. It is brought down chiefly in the two combinations of **ammonia and nitric acid**, in which forms farmers pay large prices for nitrogen when they purchase such artificial fertilizers as sulphate of ammonia and nitrate of soda (pp. 118-19). Analyses of rain-water made at nine different places in Europe, between the years 1865 and 1880, gave an average of 10·23 lb. of nitrogen per acre per annum brought down in the rainfall, the least quantity being 1·86 lb. per acre at Kuschen and the greatest 20·91 lb. per acre at Proskau. The total quantity of nitrogen supplied in the annual rainfall at Rothamsted is probably 4 to 5 lb. per acre, which is considerably less than the average of 10·23 lb. above mentioned.

TABLE XIV.—WEIGHT AND COMPOSITION OF RESIDUES OF CROPS.

	Lb. per acre.			
	Crop Residue.	Nitrogen.	Phosphoric Acid.	Potash.
Good clover,—roots	6503	65·0	27·0	—
Oats,—roots and stubble ...	2200	25·0	28·0	24·0
Timothy grass,—roots ...	2240	31·1	7·0	8·4

The **remains of plants**, particularly their roots, which accumulate in the soil, are an obvious source of gain, and serve to confer, especially upon the surface-soil, some important characters. It is this plant refuse which constitutes the main source of the **humus**, which is an indispensable constituent of all fertile soils. In Table XIV. are some figures showing, in certain cases, the ascertained weight of crop residues (water-free) per acre, together with the quantities of nitrogen, phosphoric acid and potash contained by these.

Table XV. shows the weight of roots, stones, fine soil, and water contained in one acre of land, to a depth of nine inches, at Rothamsted, in a field that had been in grass for nearly thirty years. The proportion of stones is higher than in any of the arable fields at Rothamsted.

It is seen that, after nearly thirty years, more than 4½ tons of air-dried **roots** had accumulated per acre within a depth of nine inches from the surface. These roots gave on analysis 0·75 per cent. of nitrogen, equivalent to 78 lb. of nitrogen per acre.

TABLE XV.—ROOTS, STONES, FINE SOIL, AND WATER IN ONE ACRE OF GRASS LAND, NINE INCHES DEEP.

	Lb.		Tons.	Per cent.
Roots, etc.	10,400	=	4·6	0·3
Stones, etc.	904,387	=	403·7	26·9
Fine soil (dry)	1,908,978	=	852·2	56·7
Water	543,150	=	242·5	16·1
Total	3,366,915	=	1,503·0	100·0

The intentional application in the course of tillage of **natural manures and artificial fertilizers** is an obvious source of **gain of material** to the soil. Dressings of clay, chalk, lime, marl, etc., upon soils that respectively need them are equally substantial sources of gain.

The nitrogen contained in humus is known as **organic nitrogen**, that is, nitrogen combined with carbon. In *this form it is scarcely, if at all, available as plant food;* in order to become so it has to undergo a chemical change known as **nitrification.** This change results in the conversion of the nitrogen by oxidation into nitric acid, the combination of which with some soluble base in the soil, such as lime, or potash, or soda, produces a nitrate, which can be taken up in solution by the rootlets of plants. A plant is capable of acquiring nitrogen from the soil in the form of either nitric acid or ammonia. As a matter of fact, however, the process of nitrification

is so constantly going on that far more nitrogen is taken up in the form of nitrates than in any other form.

Nitrification is brought about through the vital activity of certain organisms that live in the soil. They belong to a group of living bodies (bacteria) which are so small that the highest powers of the microscope are necessary to discern them. Ammonia is converted into nitrous acid and nitrites by two organisms named *Nitrosomonas* and *Nitrococcus*, and nitrites into nitrates by another called *Nitrobacter*. Under the influence of the nitrifying bacteria, and of other organisms, the organic matter in the soil is converted into water, carbonic acid, and ammonia, and the latter finally into nitric acid.

The conditions most favourable to the activity of the nitrifying bacteria are that the soil shall be moist, and porous enough to permit free access of air. The latter is indeed essential to them, and many other *aërobic* forms. The temperature must be sufficiently high, nitrification being most active in the summer months, and ceasing as the freezing point is approached. The soil must contain some base with which the nitric acid produced can combine; usually this base is furnished by the lime of carbonate of lime, so that much of the nitrogen which enters plants does so as nitrate of lime (calcium nitrate) in solution. Too much moisture operates against nitrification, and in a water-logged soil, such as a peat-bog, nitrification will not take place to an appreciable extent, because the access of air is prevented.

It has long been known that leguminous plants (clover, peas, beans, etc.) add to the nitrogenous plant-food in the soil, and thus play a very important part in the rotation of crops. The matter was not fully understood until 1886, when Hellriegel and Wilfarth showed that the numerous small swellings, or nodules, present on the roots of such plants contain innumerable bacteria (*Pseudomonas radicicola*) capable of 'fixing' the nitrogen contained in the air of the soil, with the ultimate production of nitrogenous compounds serving as plant-food. Soil in which a leguminous crop has been grown

contains enormous numbers of Pseudomonas in a resting stage, and able to become associated with the roots of a subsequent and similar crop. Advantage has been taken of this fact in reclaiming barren heath land, incapable without special treatment of growing such plants as clover or beans to a profitable extent. After suitable tillage in preparation for, say, clover such land has been 'inoculated' with 8 cwt. per acre of soil from a clover field. When sown with clover an abundant crop has resulted.

Several partially successful attempts have also been made to prepare laboratory cultures of Pseudomonas for the purpose of treating seeds and inoculating soil. **Nitragin** was the first material of the kind. It was prepared by Nobbe in various forms supposed to be adapted to different leguminous species, it being assumed that Pseudomonas radicicola exists in a number of 'races,' associated with distinct species. None of these preparations have so far attained practical success.

It has since been discovered that there are other nitrogen-fixing bacteria which live in the soil, the most important being *Azotobacter chroöcoccum*, a widely distributed aërobic form, dependent for its activity on the presence of calcium carbonate.

In opposition to the process of nitrification which is constantly going on in the soil, there is also a process of **denitrification,** whereby nitrogenous compounds are broken down with the ultimate liberation of free nitrogen into the air. This takes place when a large amount of organic matter is present. It is the work of certain bacteria which only thrive when free oxygen is excluded, and are therefore termed *anaërobic.*

Fungi of the Soil.—The complex chemical processes that are constantly going on in the soil are not only associated with bacteria, but with moulds and other fungi that are abundantly present. The action of these affords a promising field for research in which comparatively little has so far been done, and the same is true for the myriads of microscopic animals (Protozoa) that also live in the ground.

It is, however, desirable to say a word on *mycotrophic* plants, *e.g.*, heath and many trees, in which the roots are covered by a feltwork of delicate fungus fibres, to which the general name of **mycorhiza** has been applied. There can be no doubt that these are concerned with the preparation of plant-food for the forms with which they are associated, and it is not impossible that in some cases they are able to fix free nitrogen, though that remains to be proved. The intimate connection between two forms of life for mutual benefit, as exemplified by mycorhiza and by the bacteria in the root nodules of leguminous plants, is termed **mutualism** or **symbiosis.**

CHAPTER V.

IMPROVEMENT OF SOILS

For general purposes the most useful soils are the loams, and the best kind of soil is that indicated on page 15. Garden soils, that have long been subjected to spade culture and generous manuring, are of this character. As a rule, however, soils are more or less deficient in one or more useful properties, and this is notably the case in the soils of farms which undergo the usual course of field cultivation. It is the object of the cultivator to make good such deficiencies, and so to bring the soil into better condition. This may be effected in various ways.

Soils consisting to an undue extent of one ingredient are **poor.** A soil which includes an excessive percentage of clay, or of sand, or of peaty matter, needs some corrective before it can be cultivated to the best advantage. The most obvious course to pursue is to apply to the soil, and to mix with it, that in which it is deficient. Hence have arisen various processes for improving the soil, such as chalking, liming, claying, and warping, to which may be added paring and burning, and green manuring.

Peaty soils, and others containing too much organic matter, become what is termed 'sour,' owing to the excess of organic acids which develop in the land as the vegetable matter decomposes. Lime, by combining with such acids renders them harmless; hence **chalk** or, if more convenient, **quicklime**, is carted on to such land, allowed to crumble, then spread and ploughed in.

Marl is clay containing variable quantities of carbonate of lime; it may be called a calcareous clay. The chalk marl of Farnham contains 66 per cent. of carbonate of lime, the clay marl of Kimmeridge has 34 per cent., and the Keuper marl of Worcestershire 8 per cent. Marl is put on land chiefly for the sake of the lime it brings with it, but on sandy soils it is useful for increasing their coherence and water-holding capacity, on account of the clay it includes. Old marl pits are common in parts of Cheshire, and elsewhere.

By **warping** is meant the covering of land with the sediment deposited from silt-laden streams or floods. It is practised in Lincolnshire and adjacent districts, usually on the flat borders near the mouths of sluggish rivers. The warp makes a rich top-dressing for the land, and its effect will be seen for from 15 to 20 years. In the notable case of the valley of the Nile, the crops are dependent upon the annual overflow of the river, not only for manure, but also for moisture.

Paring and burning are occasionally resorted to on clay soils, and on soils that have become very foul from the presence of couch and other troublesome weeds. The surface is pared off, gathered into heaps, and fired, the ashes—partly of plants and partly of burnt earth—being returned to the land. A stiff clay soil may be rendered more open and porous if heaps of the clay are burnt to a ruddy brown colour, and then mixed again with the land. Clay that has been burnt does not, when moistened, resume its plastic character. The plasticity of clay is due to *combined* water, and this is driven off in the process of burning. Paring and burning destroys weeds, improves the draining capacity, and renders the silicates more soluble, potash being set free. But, on

the other hand, it destroys organic matter, including nitrogenous compounds.

Green manuring is a simple way of improving a soil that is deficient in organic matter or humus. Upon a light sandy soil, for instance, the seed of a quick-growing crop, such as mustard or vetches, may be sown, and when the plant has attained a convenient height it is ploughed in. The crop thereby returns to the land not only all the matter it took from the soil, but a much larger quantity of carbonaceous material which it obtained from the air. Leguminous crops (beans, clover, lucerne, etc.) possess an additional advantage, in that they collect from the air not only carbon by means of their leaves, but also nitrogen, through the medium of the bacteria in the root nodules (p. 39). Such crops, therefore, may serve as sources of nitrogen to the soil.

Though vegetation cannot thrive upon a soil that contains no moisture, it does not follow that because a soil is filled with moisture it is therefore well adapted to plant growth. Everything depends upon the condition in which such moisture exists. If it is stagnant, that is, if it takes the form of standing water, the soil will, for practical purposes, be barren. What is required is that the moisture in the soil should take the form of moving water, carrying with it plant-food in solution, and drawing after it the atmospheric air. It is to promote this flow of water—especially of rain water—through the soil, that the operation of **draining** is resorted to.

Various indications serve to show **when land needs draining.** After a fall of rain, the water collects in puddles upon the surface. Upon arable land, the crops are poor, and ill-coloured in the spring time, whilst such weeds as horsetail, coltsfoot, and bistort spring up. Land of this kind works badly under the plough, and it is difficult to prepare seed-beds upon it. Upon undrained grass land, rushes, sedges, tussock grass, and similar weeds usurp the place of the desirable grasses. Plovers, starlings, and other insectivorous birds commonly frequent land that needs drainage.

Ill-drained soils are always cold. The water with which the land is charged slowly evaporates into the air. In the conversion of water into vapour a large amount of heat is consumed, and it is the sun's heat, that would otherwise warm the land and promote plant-growth, which is thus diverted. Independently of this, water has a greater capacity for heat than most other substances, that is, to raise its temperature a given extent, water requires more heat than other bodies.

Land is drained with the object of promoting the percolation of water and air. Sandy soils by their texture, some soils by their slope, and others by the character of their subsoil, are said to be naturally drained. Many soils, on the other hand, have to be subjected to a system of **artificial drainage,** usually by means of pipes, before they arrive at the best condition for successful cultivation. These drain-tiles, or drain-pipes, are made of burnt clay, and unsound ones should always be rejected. The pipes are placed end to end at suitable depths, with a gentle inclination of not less than 1 in 220, along the entire course, in the direction of the surface.

There is a relation between **the depth of drains and their distance apart**—the nearer they are laid to the surface the closer are the lines of drain-pipes brought together. In a very light soil, a single drain at a suitable depth may serve to control a large area; whereas, in a stiff clay, the drains may need to be laid only 15 feet apart, and not more than 3 feet below the surface. In practice, 21 feet is an ordinary distance apart on heavy land, with a depth of 3 or 3½ feet. On light lands the width between drains may be extended to about 60 feet. In determining the direction of drains, it does not follow that the greatest slope available should absolutely be taken.

In land that drains freely, the water that fills the drain-pipes comes from below rather than from above. It is a familiar fact, proved in the sinking of wells, that at a certain depth water is reached. The surface of this underground water—the water-table (p. 25)—oscillates, approaching nearer to the ground after heavy rains and

receding farther downwards after drought. The chief function of drains is to tap this reservoir of underground water, and so prevent the water-table from rising to such a height that moisture would stagnate around the roots of plants and thus hinder their growth.

In cases of **artificial draining** it is necessary that ditches and other open watercourses should be kept clear and unobstructed. Attention to this point will often lead to the disappearance of defects at some distance away. **Main drains** should be 3 inches lower than **furrow drains,** and the **outlets** should be turned slightly down stream, and be brick-faced, with a grating to guard

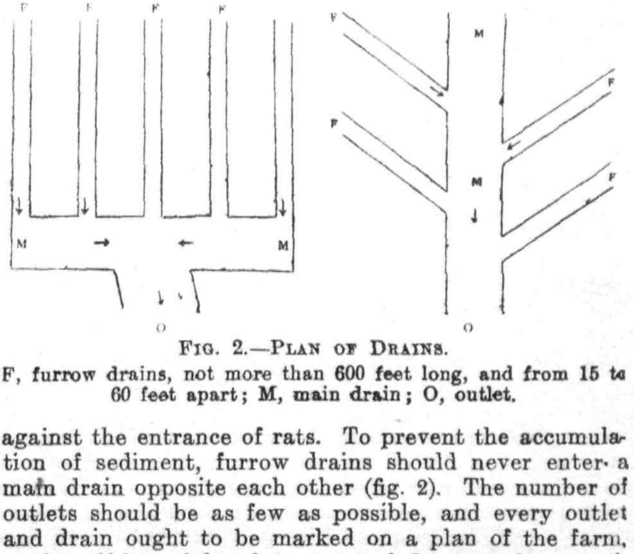


FIG. 2.—PLAN OF DRAINS.

F, furrow drains, not more than 600 feet long, and from 15 to 60 feet apart; M, main drain; O, outlet.

against the entrance of rats. To prevent the accumulation of sediment, furrow drains should never enter a main drain opposite each other (fig. 2). The number of outlets should be as few as possible, and every outlet and drain ought to be marked on a plan of the farm, so that, if lost sight of, any one of them can be traced. Where springs occur they must be drained a few inches lower than the rest of the land. In places where there is a risk lest roots of trees or of hedgerow plants should enter drains, and thereby choke them, it is well to use socketed pipes, with cemented joints.

The various acts of tillage, such as ploughing,

harrowing, rolling, hoeing, etc., are all directed to the amelioration of soils. The primary improvement they effect is in the mechanical condition of the land, but, as a consequence of this, the weathering agencies get freer access to the recesses of the soil, and the result is an addition to the store of soluble plant-food.

CHAPTER VI.

AGRICULTURAL IMPLEMENTS

IMPLEMENTS FOR WORKING SOILS

The implements in use at the beginning of the last century were of a primitive and clumsy type, wood having been largely employed in the construction of those parts now made with iron or steel. They were built with

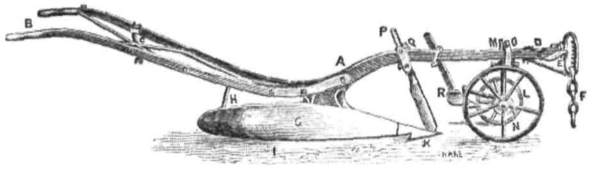


FIG. 3.—SINGLE-FURROW PLOUGH.

A, beam.
B, handle or stilts.
C, handle stay or brace.
D, quadrant head.
E, sliding-head.
F, draught chain.
G, breast or mould-board.
H, breast stay.
I, mould-board-rest.
K, share.
L, land wheel.
M, land-wheel standard.
N, furrow wheel.
O, furrow-wheel standard
P, coulter.
Q, coulter clip.
R, skim-coulter.

little regard to sound mechanical principles, consequently they were heavy in draught and deficient in execution. Improvements have gradually been made, but, as may be gathered from the successive volumes of the *Journal of the Royal Agricultural Society of England*, with striking rapidity during the last three-quarters of

a century. The spade and other hand implements are described elsewhere (p. 92).

THE PLOUGH.—The early Egyptian plough had a share, or, strictly speaking, an iron point, but no coulter or wheels; the early Greek plough had wheels as well as a share. The Bayeux Tapestry illustrates the Saxon ploughs of the eleventh century as having coulters, shares, and wheels. But none of these old ploughs turned a furrow; and it was not until the middle of the seventeenth century that the rude plough of antiquity was improved in any important particular. Even then the progress was slow, and such improvements as were effected were usually confined to limited districts.

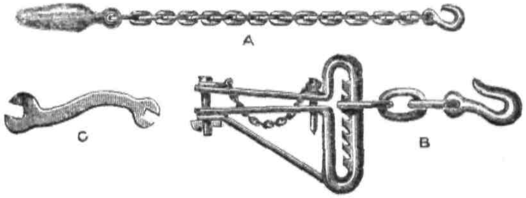


FIG. 4.—PARTS OF PLOUGH.
A, drag weight and chain. B, hake and chain.
C, spanner.

The mould-boards continued to be made of wood, and it was not until 1760 that Small introduced the Scotch swing plough, of which the beam and handles were made of wrought iron and the mould board of cast iron. Wooden mould-boards were still commonly used until about 1830. Nevertheless, at the beginning of the last century the self-sharpening chilled cast-iron ploughshares, the same as those now universally used, were invented, and plough bodies were made which could be taken to pieces, and the parts replaced by the ploughman in the field.

Since that time there have been no radical changes in the principles governing the construction of ploughs, although great advance has been made in perfecting the different parts.

The parts of the common plough (figs. 3, 4, 5)—many

or all of which are present in other ploughs—taken in the order in which it is convenient to fix them when putting the plough together, include the **beam**, to which are fitted the **handles** or **stilts** at the back end, and

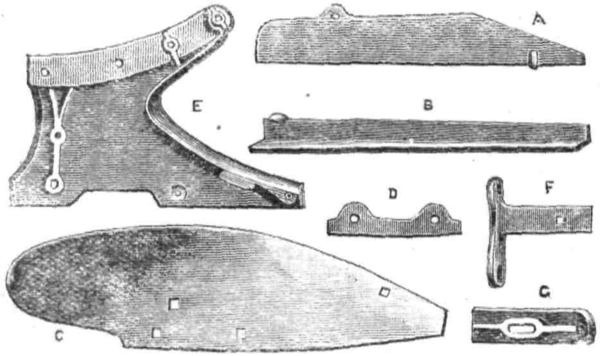


FIG. 5.—PARTS OF PLOUGH.

A, side-cap, or land-cap.
B, slade.
C, breast; D, its rest, or 'footing.'
E, cast frame, or body.
F, frame coupling.
G, breast coupling.

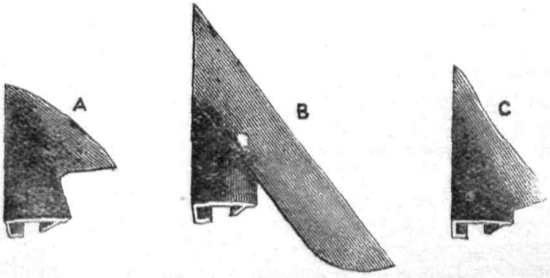


FIG. 6.—FORMS OF PLOUGHSHARES.

A, for square work in loams and land free from stones.
B, paring share for skimming stubbles.
C, pointed share for stony land.

(fig. 4) the **hake** and **chain** (sometimes called the bridle) at the front end. The beam carries all the parts.

The handles are for steering and balancing the plough; whilst the hake and chain provide the means for attaching the plough to the **whipple trees.** The hake has notches by means of which the chain may be adjusted as required; if the plough will not draw into the ground readily the chain is lodged in one of the upper notches; whilst if the tendency is to draw in too deeply the chain is linked in one of the lower notches, thus causing the plough to run without undue inclination either into or out of the soil, and relieving both horses and man of undue or unnecessary strain. The hake can be moved sideways along the **quadrant head,** which is provided with holes and a pin in order to fix the hake in any required position. If the plough runs away from the unploughed land, the hake must be set to the right; and if it runs too much to the land, the hake must be set more to the left. In many ploughs the hake head (fig. 4) is replaced by a **draught chain** attached to the beam in front of the body and the vertical and lateral adjustment is obtained by means of the **sliding head** (*see* fig. 8). Both systems have their advantages and advocates.

The **frame** or **body** (fig. 5, E), which carries the whole of the ploughing parts except the coulters, is bolted to the beam.

The **share** (fig. 6), the object of which is to make the horizontal cut of the furrow, is fitted on the fore-end of the frame, or on a lever neck, which is made adjustable, so that, by raising or lowering the rear end of the lever-neck the share is set at a sharper angle, the better to enter hard ground, or made to run level as desired; this is called 'altering the pitch of the share.' A few manufacturers in Great Britain have recently introduced what is called a **bar point share** (fig. 7). This consists of a strong steel bar about a yard long, chisel-pointed at both ends, which can be reversed and advanced as wear takes place, the wing of the share being a separate wearing part. It is claimed for the ploughs fitted with such bar point shares that they will face rocky land better than anything else.

The **slade** is attached to the under side of the body, its duties being to support the plough, and to make it

run steadily. The object of the **side-cap** or **land-cap** is to take the thrust of the breast against the **land side** and to keep the earth from falling into the **furrow**.

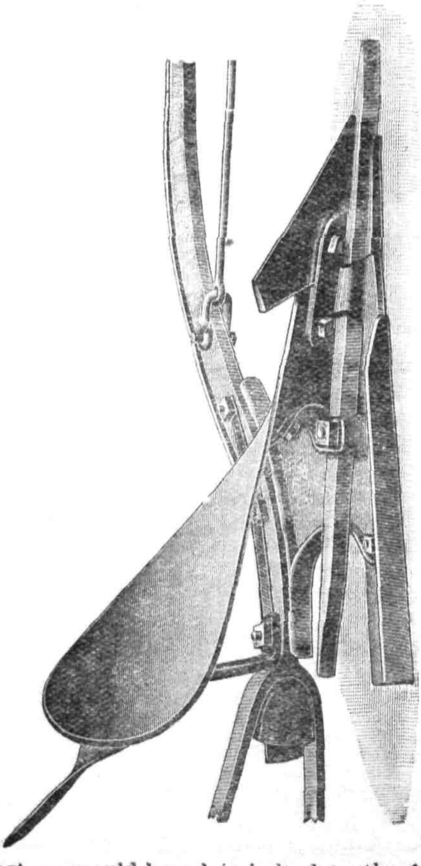


FIG. 7.—PLOUGH WITH BAR POINT SHARE.

The **breast** or **mould-board** is bolted to the **frame**, and kept adjustably rigid by means of the **frame and breast couplings** and the **breast-stay**. The **rest** supports the

breast on the under side, and, taking the friction, prevents wear on the bottom of the breast, and is itself replaced at trifling cost.

The **lever-neck,** when used, is attached to the frame under the breast. Many ploughs, however, are without a lever-neck, in which case the shares are made more or less pitching, in order to suit the nature of the soil. The **wheels** are fixed to the fore-end of the beam by a cross-bar and beam-clasp. The **cross-bar** is attached at right angles to the fore part of the beam by means of

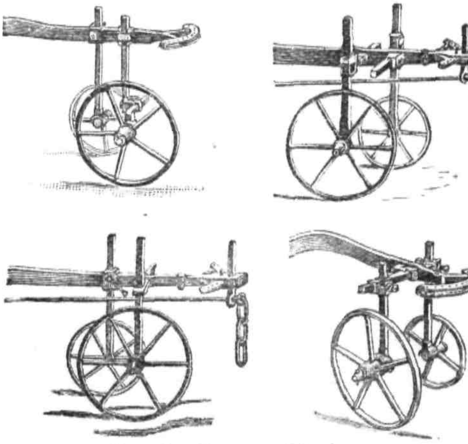


FIG. 8.—PLOUGH WHEELS.

the **beam-clasp,** which is held in its place by a set screw. The large or **furrow wheel** is placed on the right of the cross-bar, and the standard which carries the wheel is held in position by **wheel sockets** and **set screws** (fig. 9 E). It runs in the furrow, and regulates the width of the furrow slice. The small or land-wheel is similarly attached on the left of the cross-bar, and runs on the unploughed land to control the depth of the ploughing.

The ploughing is regulated by the manner in which the wheels are set. If it is desired that the furrow should be ploughed deeper the land wheel is set higher, and

vice versâ. The width of the furrow is regulated by the furrow wheel, the furrow widening in proportion as the furrow wheel is set further from the beam. The width of the furrow is, in fact, determined by the distance or width between the cut of the coulter and the track of the furrow wheel. The details of the wheel fastenings vary according to the district, some localities having a preference for one form or another, but the above description gives the general principles of the adjustment for width and depth.

The wheels are fixed to the fore end of the beam by one or more cross-bars, or by sliding axles to the lower end of the wheel standards, as shown in the illustrations (fig. 8).

The **coulter** is attached to the beam by means of the **coulter clip** and **loops** (fig. 9, D). Some skill is required to fix the coulter in the correct position, as it is necessary to place it at different angles according to circumstances, but, as a rule, the point of the coulter should be set so that it is almost close to the share point. The coulter makes the vertical cut of the furrow slice. The **skim-coulter**, which is attached to the beam slightly in front of the coulter, is really a plough in miniature (fig. 9, C). It pares off the top of the furrow on the left side, when this is rendered desirable on account of plant growth upon it, or when it is necessary to cover in dung or other material lying on the surface. The small breast of the skim-coulter turns the loose material into the horse-walk, where it immediately becomes buried by the furrow.

Another method, frequently followed, of fitting the plough together, is to begin with the body, consisting of the frame, the slade, the share—either with or without lever-neck—the breast, and the couplings which attach the breast to the frame. These practically make the plough. The beam is attached to the implement for the purpose of drawing it through the ground, for the fixing of the wheels for regulating the depth, and for attaching the coulter to make the clean vertical cut. The handles are put on to the rear end of the body for the purpose of guiding the plough.

In working the plough the following **instructions**, should be observed:—

Ploughs with two wheels should, in turning the land's end, be balanced on the furrow wheel.

In ploughing the last furrow, the land wheel is turned inwards or drawn up out of the way.

On wet, sticky soil, where the land wheel clogs, a slide foot may be used instead of the wheel, and a short

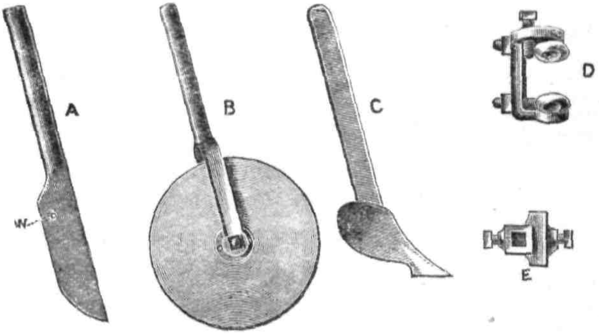


Fig. 9.—Parts of Plough.

A, coulter (W, hole for attaching drag weight and chain—fig. 4, A).
B, disc-coulter.
C, skim-coulter.
D, coulter clip and loops.
E, wheel socket and set screws.

breast, which turns the furrow more quickly, will be found preferable to a long breast.

In very hard land, ploughs go more easily if the draught chain is lengthened three or four feet.

When the ground is hard or stony, a share with a long point should be used, and, as the point wears off, the lever-neck—if present—must be raised higher.

On clay or soft land, or when ploughing without wheels, a share with short point should be used, and the lever-neck fixed lower. The head or draught chain should also be lowered, so as to prevent the wheels cutting into the ground.

The skim-coulter should be set so as only just to clear the herbage on the surface—the shallower the better; the hinder part should not be too high from the ground, but set as level as possible. In ploughing the coming-back furrow, after drawing the first on the ridge, the skim-coulter should be set moderately deep, so as effectually to bury the grass.

A drag chain should be used on ley ground, as also when ploughing in green crops, stubbles, and long dung.

On reaching the end of a furrow the plough should not be lifted by the ploughman to the next piece, but should be brought out by simply pressing on the handles, thereby using them as a lever. The plough is thus turned over on the right-hand side, balanced on the large or furrow wheel, not the small or land wheel,

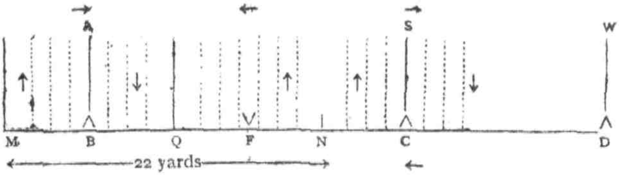


FIG. 10.—DIAGRAM SHOWING MODE OF PLOUGHING
[NOTE.—M B = B Q = Q F = F N = N C = 5½ yards.]

and so drawn towards the next piece. The turning can be done by a boy, being a matter of skill rather than of strength.

The breasts of ordinary ploughs are fixed on the right-hand side, so that they turn the furrow slice on the right-hand side only. It is therefore necessary to work in ridges or lands, the width of which may be varied from 8 feet to 66 feet, according to the climate and nature of the soil.

Perhaps the best mode of ploughing in dry climates with such ploughs is in 22-yard lands, as illustrated in fig. 10.

Step off from the left-hand boundary of the field 22 yards, as shown in the diagram. Divide this into two equal lengths of 11 yards each, M Q, Q N. Divide

again that portion nearest the hedge or boundary into two equal lengths of 5½ yards, M B, B Q. Upon the centre line A B of this, throw a furrow slice from each side to form the ridge A B. Keep ploughing round the ridge B, in the direction of the arrows, till 5½ yards of ridging or gathering are done each side, as shown in the diagram. This first piece being finished, step out 22 yards, B C, from the middle of the ridge A B; this distance will extend 5½ yards beyond the first new ridge C S. Proceed to make ridge C S, and plough round it 5½ yards on each side, as in the former case. There will then be 11 yards, Q N, of unploughed land between the two ridges A B and S C, which proceed to plough out (casting or splitting), first on one side, and then on the other, until the work is finished in the middle, where there will be an open furrow F.

Now proceed to step out 22 yards, from the ridge C S, to get the centre for the new ridge (shown at D W), make a ridge on D W, and plough round it 5½ yards on each side as before, then 5½ yards on the right side of ridge C S being already done, there will be 11 yards of unploughed land between the two ridges C S and D W, which plough out as before.

From D, step out 22 yards to form the centre of another ridge, and so on until the field is finished.

If it should happen that an odd piece is left over on one side, a separate ridge must be made for it.

Where the fields are large, set out all the ridges first, so that several ploughs can work together in the same field.

Change the position of the ridges at every fresh ploughing, beginning the new ridges in the old furrows. In the diagram, B A, C. S, are ridges; F is a furrow.

On heavy soils, as it is often impossible to get the surface-water away quickly enough, unless the land is laid up in ridge and furrow, the mode of setting out the lands differs. The distance from the crown of one ridge to the crown of the next varies according to the nature of the land. Where a strong loam rests on a rather stiff subsoil, 10-yard lands may be sufficient; the same soil with a very retentive subsoil would not be safe in more

than 7-yard lands; whilst a clay soil resting on clay should not be laid up in more than 6-yard lands, and even 5-yard or 4-yard lands are practised. The smallest lands are laid up for wheat, when, to avoid treading on the seed-bed, they are ploughed so as to be just as wide as the corn-drill; the horses then walk up the open furrows, so that all treading, and consequently puddling are avoided. Of course, these are flat, so that the drill runs evenly over them.

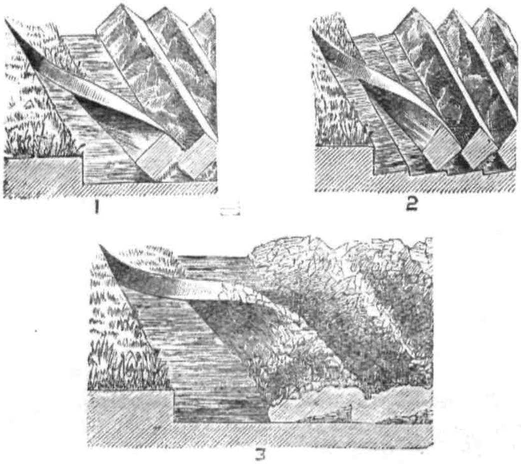


FIG. 11.—FORMS OF FURROWS.

(1) Rectangular furrow, unbroken; (2) crested furrow, unbroken; (3) wide furrow, broken.

The three forms of furrows shown in fig. 11 are those most commonly employed. The rectangular furrow (1) is obtained by a flat cutting share, and an upright coulter, so that the sole of the furrow is flat. The crested or high cut furrow (2) is obtained by using a share which is raised on the wing side, and an undercut coulter. In the latter furrow a larger surface is exposed to the influence of the weather, and it is therefore frequently adopted in winter ploughing, or where broadcast sowing

is practised. The wide broken furrow (3) is the work of the digging breast plough, which is specially suitable for the purpose of producing tilths.

Land turned up with the digging plough is reduced to a light condition, which makes it practically ready for planting, though if left exposed to the weather any heavy rain is likely to beat it down to a 'sad' condition, requiring the work of a cultivator or other implement to open it up. If the ploughed land has to lie for a time, angular furrows (fig. 11, 1 and 2) are preferable, as they withstand the beating down effects of heavy rain.

The following are the **points of good ploughing**:—

1. The furrows must be straight.
2. The ridges must be well set.
3. The lands should be of equal size and the number of furrows in each should be the same.
4. The furrows should be neatly packed, and all surface rubbish well covered.
5. The work must be well finished.

The **types of plough** in use in this country and in various parts of the world are exceedingly numerous, and differ in their most essential features, such as the shapes of the cutting and turning parts, wheel fastenings, beam, handles, etc., and no universal plough has yet been found which will suit all the varying conditions of soil and climate. For our purpose here ploughs may be divided into four classes, viz. :—

1. Single-furrow ploughs, one of which has just been described in detail.
2. One-way ploughs, including turn-wrest, balance, and turnover ploughs.
3. Double-furrow and multiple ploughs.
4. Special purpose ploughs.

Of these, Class 1 may be subdivided into ploughs for narrow unbroken work, and ploughs with short breasts for wide broken work, commonly known as **digging ploughs.** In the case of the latter, the coulter, rest-iron, breast-stay, and side-cap, are often found not to be necessary. The shin of the breast, and the skim-coulter, make the vertical cut, which, however, not

being exactly perpendicular, does away with the necessity of the side cap. The digging plough inverts the land, and, as it has a short concave breast, it throws the soil loosely over and pulverizes it, thus effecting very similar work to that of the spade. The share is

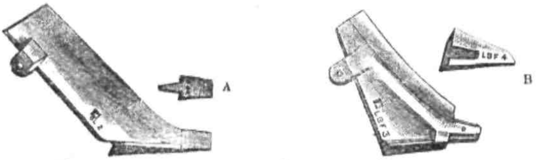


FIG. 12.—SHARES OF DIGGING PLOUGHS.
For mixed Soil—A, Reversible pointed; B, Cap pointed.

usually fitted with a chisel point, though this is not invariably the case. Some of the renewable points for the shares are shown in fig. 12.

Single and double or multiple ploughs are used in the breaking up of land as well as in the subsequent operations.

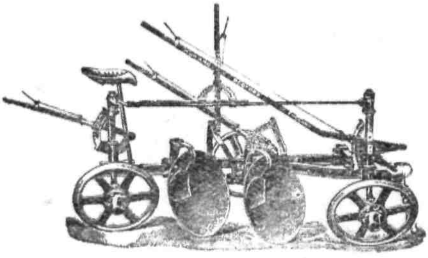


FIG. 13.—DISC PLOUGH.

Under **special purpose ploughs** are classed the double-breasted ridging or bouting ploughs, the subsoil, potato raising, trenching, and other special ploughs and their purpose is denoted in the name.

A somewhat recent development is the **disc plough.** The share and breast of the ordinary plough is replaced by a large steel concave cutting disc (fig. 13). In some

parts of the world this implement is reported to suit the conditions of soil and climate.

Single-furrow ploughs are again subdivided into swing ploughs, one-wheel ploughs, and two-wheel ploughs, and ploughs with a gallows or loose fore-carriage.

The one-wheel implement is used on sticky land, where it assists the holder to keep the plough steady without greatly interfering with the nature of the work done. The two-wheel plough (fig. 3) is much more commonly used, and, when properly set, leaves comparatively little for the holder to do. The furrow-slice with this class of ploughs is turned over by a cast-iron or steel mould-board, which is made on the lines of a twisted strap, or somewhat like the screw of a steamer. This mould-board, drawn through the land, causes the cut slice to turn over, and at the same time consolidates it more or less by pressing it against the preceding one. Two wheels are usually attached to digging ploughs, turn-wrest ploughs, and most of the special purpose ploughs. Ploughs with a gallows fore-carriage and ploughs with a loose fore-carriage facilitate the turning at the headlands, but lack the simplicity of the fixed wheels.

One-way Ploughs.—Where ploughs of this type are used, one setting is sufficient, as all the furrows are turned in one direction, thus avoiding the loss of time and extra treading caused by finishes. The **turn-wrest plough** (fig. 14) is used on hilly land, being worked horizontally along hillsides and turning the furrows all in one direction, thus obviating the necessity of turning any of the furrows uphill. The great extension of market gardening and fruit farms has led to the extended use of the horse balance plough, as the land between the rows can be easily ploughed, as well as small pieces of land between the crops not yet harvested.

Double (fig. 15) and **multiple ploughs** are used to economize both horse and manual labour. **Double-furrow ploughs** are frequently employed to break whole land, and now that they are made lighter, and with special arrangements for turning at the headlands, they might

be used more frequently than is at present the case. The turning, and also regulation of depth of working, are facilitated by connecting the wheels with a lever, which adjusts their position. They also do good work

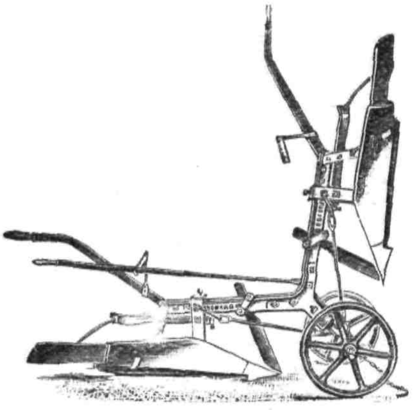


FIG. 14.—TURN-WREST PLOUGH.

upon land that has been once moved. In some districts they are largely used, and often result in a saving of horse labour, as three horses will plough two furrows, whereas, with a couple of single-furrow ploughs, four

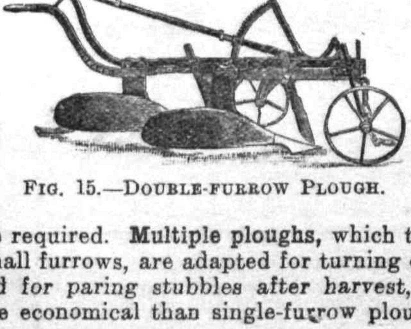


FIG. 15.—DOUBLE-FURROW PLOUGH.

horses are required. Multiple ploughs, which turn three or four small furrows, are adapted for turning over light tilths, and for paring stubbles after harvest, and are much more economical than single-furrow ploughs.

Special purpose ploughs include many varieties, and attention may be directed to those most commonly used. The **double-breasted** or **ridging plough** is employed for laying up land in ridges for root growing, and for moulding up potatoes. The **subsoil plough,** either single or double, is made to travel in the furrows behind an ordinary plough, the tine running along the horse-walk several inches deeper than the land has already been ploughed; or the tine is sometimes fixed to the common plough, and the ploughing and subsoiling are effected in one operation. In this way land which, a few inches below the surface, has been rendered hard through compression or from natural causes, and has formed what is known as a pan (p. 27), becomes loosened. As a result the roots of plants can extend more deeply, excess of water can drain away more readily, and the upward flow of moisture by capillarity (p. 25) is not checked.

The **potato-raising plough** is used for splitting open potato ridges, thereby exposing the tubers, so that they may be readily picked up. In order to facilitate the exposure of the potatoes, the breast takes the form of a raiser, a few prongs being substituted for the double-breast of the moulding plough, so that the earth, falling through the spaces between the prongs, leaves the tubers on the surface. To render the work more perfect another raiser is fixed in the place of the slade. If the hinder raiser is taken off an efficient moulding-up plough results.

Gripping ploughs are usefully employed on grass land to cut grips, or shallow watercourses, for promoting surface drainage; work which is not efficiently done by ordinary ploughs. For grass land on stiff soils a **mole-draining plough** for horse draught will render great service in getting rid of surplus water at small cost, and the effect will last for years.

Trench Ploughing.—For fruit planting it is often desirable to plough to depths far beyond the ordinary farm work, and for this purpose special heavy ploughs which work to a depth of 18 inches are made, to be drawn by horses.

Cultivators are used (*a*) for breaking up whole land, and (*b*) for stirring it after it is ploughed. They differ from ploughs in that they do not invert the soil.

The variety of implements known as cultivators, grubbers, scarifiers, or scufflers, and horse hoes, is infinite, and there is no exact definition possible. At the one extreme we find the single-row hoe for one horse, as shown in fig. 16, and at the other the heavy scuffler or cultivator requiring six horses, or the horse hoe with ten or more tines for hoeing wheat or roots. All these implements are usually provided with broad or narrow

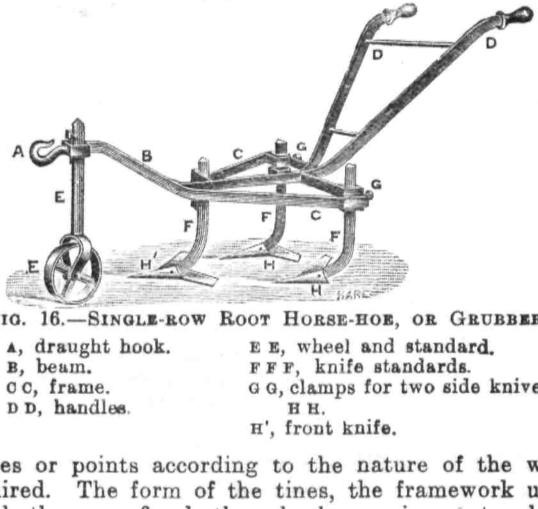


Fig. 16.—Single-row Root Horse-hoe, or Grubber.

A, draught hook.
B, beam.
C C, frame.
D D, handles.
E E, wheel and standard.
F F F, knife standards.
G G, clamps for two side knives, H H.
H', front knife.

shares or points according to the nature of the work required. The form of the tines, the framework upon which they are fixed, the wheels, carriage, etc., have perhaps received more attention from implement makers than the parts of any other farm tool, and hence in a short summary it is impossible to describe them. Harrows, however made, whether for light or heavy work, do not possess wheels, and this feature distinguishes them from cultivators.

The Disc Cultivator consists of a series of dished steel discs mounted somewhat obliquely to a travel of the machine, the discs cut up the soil and rapidly reduce it to a fine bed.

In its lighter forms it is used as a Disc Harrow.

The **cultivator, scarifier,** or **scuffler** (fig. 17), is more often used with chisel points than with broad shares; its duty is to break up furrows, so that the lighter harrows may work more freely.

HARROWS.—The **curve-tined drag harrow** is usually worked after the scuffler, and is one of the most useful of the tillage implements. It stirs the land and helps to form a good tilth, whilst by the curved form of its tines it drags out couch, and is thus most useful in all cleaning operations. **Straight-tined drags** are used to level down furrows on light chalk soils, when there is much long rubbish or haulm which requires burying, and which, if dragged out, would prove troublesome. They are not adapted for clearing land of weeds, such as couch, which have extensive underground development.

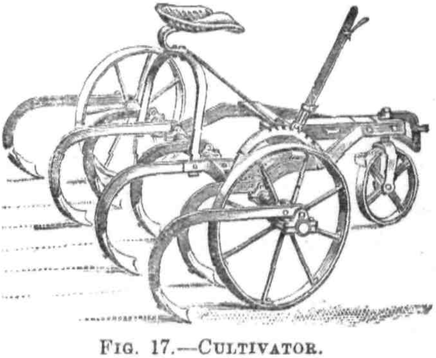


FIG. 17.—CULTIVATOR.

Light harrows are commonly made on the zig-zag principle, whereby the tines are so arranged that, while the whole of the surface of the land is operated upon, no two tines follow in exactly the same track (fig. 18)

Heavy sets of harrows are made for working with three horses, intermediate sets for two horses, whilst the lightest seed harrows, used for the final covering in of the seed, require only one horse to draw them. Harrows take the place in field culture held by the rake in garden work.

Chain harrows are constructed so that they are quite flexible. They are convenient for gathering couch, which they free from any adherent soil in the operation. They are equally useful for harrowing pastures, for which purpose those with points are best adapted.

Rollers and Pressers are made in many forms, though the main feature of rotation round an axle is common to them all. The heaviest are generally called **clod-crushers** or **presses**, and are used to reduce large clods to a size more convenient for treating with other implements, and also to bring the clods into a condition

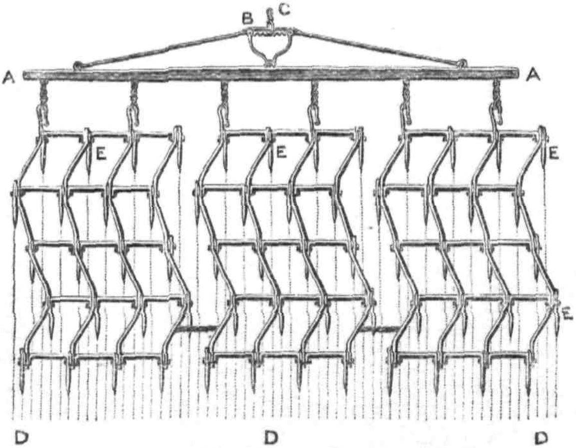


Fig. 18.—Zigzag Harrow.

A A, draught beam. A, B, C, A, whippletree.
B, hake. D, D, D, tine marks.
C, draught chain. E, E, E, teeth or tines.

more susceptible to the influence of the weather. Clod-crushers are made with discs revolving on a main axle. In the case of the **Cambridge roller** the discs are arranged so that the cylinder presents a transversely fluted surface. Other pressers are made with serrated discs which present a broken surface, the outside of the cylinder being notched so that the clods are chopped by the rough edges.

Smooth cylinder iron rollers are usually made in two or more sections, the cylinders being placed end to end

on an axle. One advantage of making the cylinder in sections is that in case one portion meets with an accident or is worn out sooner than another it can be re-

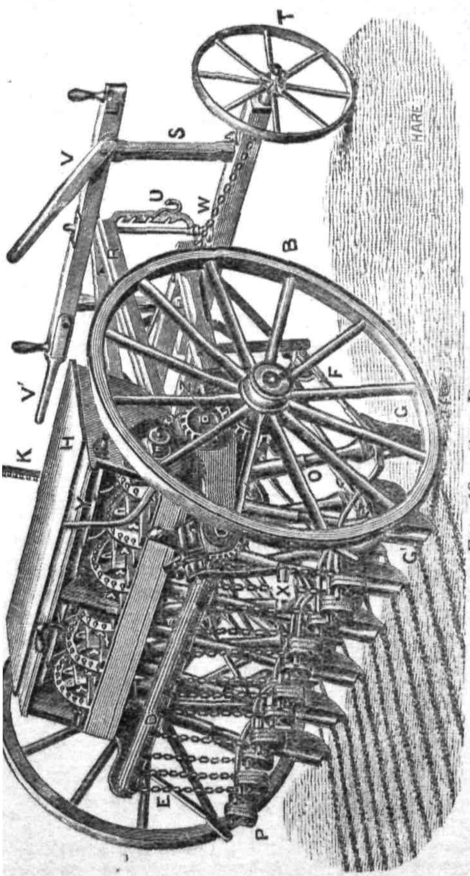


FIG. 19.—CUP DRILL.

(NOTE.—Parts of this machine are shown on a larger scale in figs. 20 and 21.)

B, travelling wheel (off side) with driving cog wheel attached.
D, hind barrel or roller, for winding lever-chains.
E, lever-chains.
F, fore lever.
G, G′, fore and hind coulter.
H, corn box.
K, vertical rack.
O, conductors or spouts.
P, lever weights.
R, steerage tongs.
S, fore carriage steerage.
T, steerage wheel.
U, draft hook.
V, V′, guide handles.
W, steadying chains.
X, windlass handle for raising levers.
Y, lever for lifting corn box out of gear.
Z, countershaft extending underneath box carrying cog wheel NP1 (fig. 21) on near side, and on off side a cog wheel gearing into nave wheel.

placed at less cost. What is of great importance is that it is more convenient at the end of the field to turn the roller round, when in sections, than when in one long cylinder, for while in this operation one end is

going forward the other revolves backward, thus preventing the 'screwing' up of the soil, and often of the crop, which is liable to occur if great care is not exercised in turning. These rollers are made in various sizes to suit the requirements of different kinds of work.

Wooden rollers, though comparatively little employed since the introduction of iron rollers, are very useful in special cases, as when it is desired to break small clods without consolidating the soil more than is absolutely necessary. They consist merely of cylindrical boles of wood attached to a frame, the axle being an iron gudgeon let into the wooden cylinder, and rotating in the upright sides of the frame.

IMPLEMENTS FOR SOWING SEED AND DISTRIBUTING MANURE

Drills.—The machines used for sowing seed may be classed as follows:—

1. Cup drills.
2. Tooth and brush pinion drills.
3. Disc drills.
4. Chain drills.
5. Force feed drills.
6. Potato planter.

The **cup-drill** (fig. 19) is the one in most common use in Great Britain. A long box is mounted on a frame to carry the seed. This box is divided into an upper chamber, or **hopper**, which connects with a lower chamber by ports or apertures regulated by slides, and through the lower a spindle runs from end to end. On the spindle several discs fixed transversely carry small spoons or **cups** set near the outside rim, at right angles to the direction taken by the discs. These cups pick up the grain as they revolve (the motion being generally given to the spindle by a nave gearing attached to the travelling wheels) and pour it into **funnels** (fig. 20), the latter being connected with **spouts**, which drop the seed into the track made by the **coulters**. These are generally attached to a mortised bar in the fore part of the frame. Each coulter works independently, but various appliances in the form of weights, springs, etc., are attached to regulate the depth to which the coulters cut and at which the seed is deposited. Fig. 21 affords a side view

of the driving gear, the travelling wheel being removed from the axle, for the sake of clearness. Except in the details of raising the seed, most drills are constructed on plans very similar to that just described.

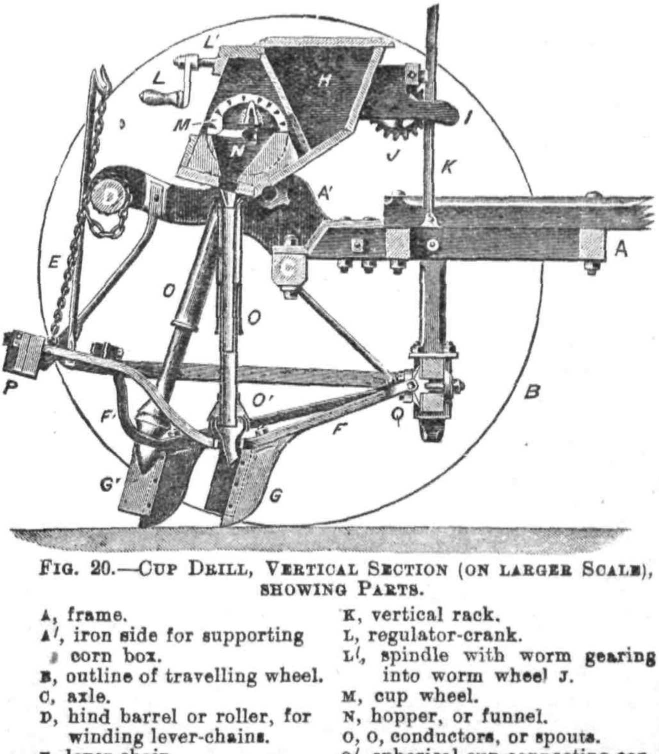


FIG. 20.—CUP DRILL, VERTICAL SECTION (ON LARGER SCALE), SHOWING PARTS.

A, frame.
A', iron side for supporting corn box.
B, outline of travelling wheel.
C, axle.
D, hind barrel or roller, for winding lever-chains.
E, lever-chain.
F, F', fore and hind levers.
G, G', fore and hind coulters.
H, corn box.
I, box-regulator.
J, worm wheel.
K, vertical rack.
L, regulator-crank.
L', spindle with worm gearing into worm wheel J.
M, cup wheel.
N, hopper, or funnel.
O, O, conductors, or spouts.
O', spherical cup connecting conductor with coulter.
P, lever weight.
Q, lever joint.
R, steerage tongs.

Tooth and brush pinion drills have the bottom of the seed box pierced with holes, which are covered by a

revolving pinion having teeth alternating with brushes, whose revolution sweeps out the seed. These drills are only suitable for level fields, and their use is restricted to special districts.

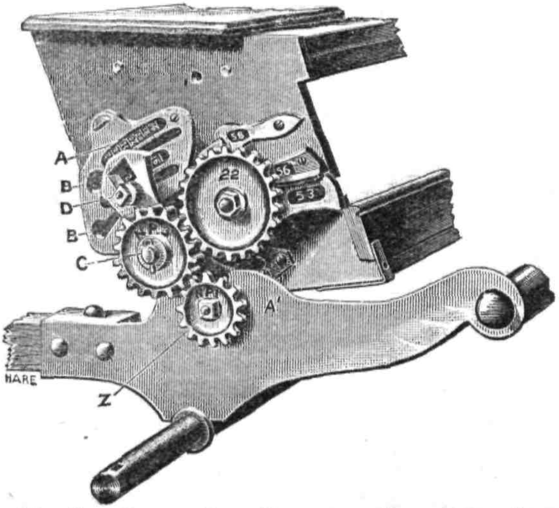


FIG. 21.—CUP DRILL, SIDE ELEVATION (ON LARGER SCALE), SHOWING DRIVING GEAR.

A, index plate.
B, B, grooves for bolt D.
C, fixed stud of radius-arm.
D, bolt by which radius-arm is held fast to index plate.
NP1, cog wheel on counter-shaft.
NP3, intermediate wheel.
22, cog-wheel on cup-barrel.
53, drop bearing for supporting cup-barrel.
58, catch for retaining drop bearing in position.
A′, see fig. 20.
Z, see fig. 19.

Disc drills are similar to pinion drills, the pinion being in them replaced by a disc having waved edges, which alternately open and close the holes in the seed box, bringing forward some seed at the same time, as an endless screw might. These are also unfitted for hill-side work.

Chain drills are provided with an endless chain, on which the seed from the hopper falls, and is thereby conveyed to the discharging funnel.

Force feed drills have the bottom of each seed hopper closed by a small spirally-grooved roller, which, revolving as the machine travels onwards, supplies seed in a regular stream to the discharging funnel.

Potato planters are drills which are made with hoppers to contain the potatoes, and an endless chain, carrying a series of cups, which passes through each hopper, every cup taking up a potato in its passage. The potatoes then fall into a tube, through which the endless chain itself returns, and as each cup emerges from the bottom of this tube, a potato drops into the furrow. Mould boards are attached so as to immediately cover the sets with mould.

Artificial Manure Distributors are made in several forms, and may be divided into broadcast and rotary distributors.

The **broadcast distributor** delivers the manure to the ground along a strip, the width of which is equal to the length of the hopper.

In the **rotary distributor** the manure is spread by the centrifugal force imparted by revolving horizontal discs, and the width covered is dependent on the speed of the discs, the weight of manure, etc.

Machines for sowing seed and manure at the same time are also made.

STEAM CULTIVATION

Ploughing, cultivating, harrowing, and drilling may all be done by steam-driven implements, and, in so far as large implements are suitable for working the land, very clever adaptations of horse implements have been made. A few years since it was confidently stated that steam cultivation would supersede horse work, but this expectation has not been realized. The large implements which are requisite where expensive engines are employed are too heavy and work too clumsily and too coarsely, besides treating the land too roughly; moreover, whilst stirring the land thoroughly, they injure it so much at times that farmers find it more economical to support a full team of horses than to lay out part of their money in steam tackle. There are some operations which may be economically done by steam

if they are well timed, but in an uncertain climate like that of England, and on comparatively small tracts of land, the occasions are few. Where steam cultivation is resorted to, it is generally done—like steam threshing often is—by men who own the tackle, and do the work for farmers at an agreed price per acre.

The best work is done by the **steam cultivator,** which is a huge grubber, and in dry seasons, whether in autumn, spring, or summer, this may be employed very satisfactorily, if not worked to too great a depth, in breaking up land, and thus forwarding the horse work. It is then particularly advantageous, as by its means large tracts can be broken up on fine days during seasons when there is not much weather favourable for cleaning land.

The **steam drag-harrow** is a broader implement than the cultivator, but is lighter in construction, and is fitted with a large number of smaller tines, which work similarly to those on the ordinary horse scuffler. It is very useful for stirring land already ploughed or broken. Its great breadth renders it capable of covering many acres in a day, and it is specially valuable as a means of forwarding horse work in spring.

Steam cultivation, as already explained, involves a large outlay, but considerable progress has been made in ploughing by direct traction, the light motors being driven by either steam or internal combustion engines, using petroleum, petrol, or alcohol. The light motors are made for the single-furrow machine, and of greater power for working multi-furrow ploughs, and which, besides ploughing, will haul loads, or, by a belt, can be used for driving machines.

So much work of this kind has been done in the Colonies and foreign countries that motor ploughs for working the various depths and widths required have led to the design of special ploughs, adapted to meet these requirements, and to withstand the pull of the tractors. Two main types have been evolved since the introduction of steam ploughing, viz., (1) balance ploughs, and (2) following the ordinary types of horse implements, single and multiple ploughs, the latter making from two to ten furrows.

IMPLEMENTS FOR SECURING CROPS

The scythe, sickle, fagging-hook, and pea-hook were formerly relied upon for cutting the whole of the corn crops, but the greater portion is now cut by horse machines. The scythe is still used when corn is badly storm-broken, and sometimes, in preference to the horse machine, on barley. It is also employed on a somewhat large scale for mowing crops intended for hay. The sickle is now rarely seen. The bagging-hook or fagging-hook, continues to be used with some frequency, especially for cutting beans. The pea-hook is the best implement for cutting field peas. The various hand implements are further described on p. 92.

HARVESTING IMPLEMENTS

Reaping Machines may be classed as: Manual-delivery reapers; Self-delivery reapers; Binders.

Manual-delivery reapers require the assistance of a man to clear the machine of the sheaf. Self-delivery reapers discharge the sheaf by means of revolving sails. Binders cut the corn, gather it into sheaves, and tie the sheaf with string.

The **manual-delivery reaper** is the least complicated of these machines, as the work to be done consists of little beyond cutting the corn. A simple frame, carried on one or two wheels, to which is attached the **finger-beam**, in which the knife works, is all that is essential. The crop is held up against the knives by the workman, and a small slatted rack controlled by his feet receives the corn as it falls; by lowering the rack the sheaf glides off. It is a drawback to this machine that the sheaves must be moved before it can work round the field again, for they fall in the track the horses have to walk along. These reapers are now only used to a limited extent. They are very light in draught.

The **self-delivery reaper** (fig. 22) is more intricate than the manual-delivery implement, as provision has to be made for causing the sails to revolve. The delivery of the sheaf is effected by the sails, which bring the corn to the knives, and then cast it free from the machine at the side. This side delivery of the sheaf

leaves the horse-walk clean, so that if the crop is wet when cut, or contains green weeds, or if hand labour cannot conveniently be found at the time, it need not be tied, but the whole field may continue to be cut without hindrance.

The force expended in working the sails, although much lessened by the improved construction of the machines, is nevertheless great; consequently the draught is much heavier than that of the manual-delivery machines.

The **binder** is a very intricate machine, and is the result of the application of a larger number of mechanical principles than are to be found in almost any other machine used upon the farm. Its construction has now reached a high degree of perfection, considering the many different operations which have to be carried out simultaneously. Viewing the size of the machine and the various acts it performs, it is relatively of easier draught than the self-delivery machine.

Making allowance for slight variations, the following is the manner in which the binders perform their work. The cut grain is first carried to one side of the machine and then lifted over the driving wheel by means of endless webs, or canvas aprons; these deliver it to an incline, down which it falls, until stopped by a lever which opposes its further progress. Against this the grain is 'packed' until a bundle big enough for a sheaf has accumulated. Then the lever which is arranged to yield before a predetermined pressure, gives way, and in doing so puts the 'binder' into gear. A curved arm, the exact equivalent of the needle of a sewing machine and threaded with string under a given tension, rises from beneath the incline and encircles the bundle with a cord, the end of which it leaves in the grasp of the knotter. Finally, this clever device first ties and then cuts the string band, leaving the sheaf free to be thrown off the machine by a pair of arms provided for that purpose.

Mowing Machines, used for cutting grass and 'seeds,' are very similar to the manual-delivery reapers, but there are two travelling wheels (fig. 23) in the place of the single wheel now used on all reaping machines. The

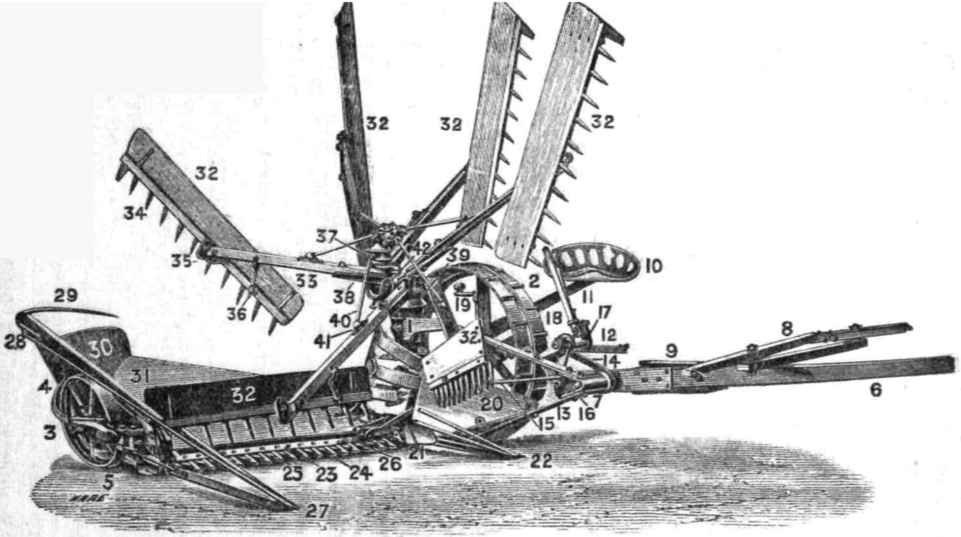


FIG. 22.—SELF-DELIVERY REAPER.

1, main bracket.
2, main road wheel.
3, swivel wheel.
4, scraper for swivel wheel.
5, swivel wheel joint.
6, pole.
7, pole joint.
8, whippletrees.
9, tool box.
10, seat
11, seat support.
12, foot bar.
13, frame irons.
14, side stay.
15, stay for platform.
16, slotted bracket and quadrant.
17, tilting bracket.
18, tilting lever.
19, raising handle.
20, shield for gearing
21, connecting rod.
22, corn lifter.
23, cutter bar, or finger beam.
24, fingers.
25, knife.
26, knife clip.
27, divider.
28, divider board.
29, top horn.
30, panel.
31, platform.
32, rakes, or sails.
33, rake arms.
34, rake teeth.
35, rake adjusting bracket.
36, rake stay for adjustment.
37, rake hanger bracket.
38, rake socket.
39, rake centre and crown wheel.
40, hanger rods.
41, hanger rod brackets.
42, dummy hanger bracket.

mower has an independent gear-frame, from which the cutter-bar, or finger-beam, hangs in such a manner as to follow freely all irregularities in the surface of the ground.

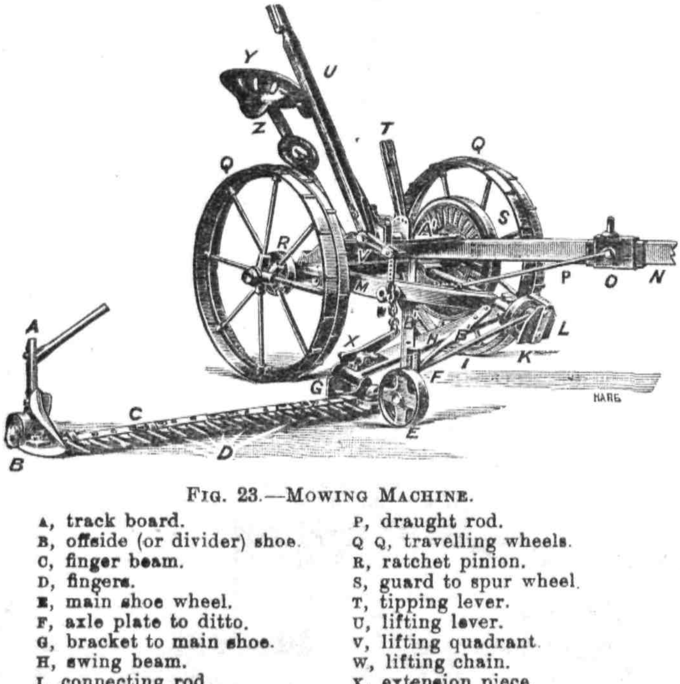


FIG. 23.—MOWING MACHINE.

A, track board.
B, offside (or divider) shoe.
C, finger beam.
D, fingers.
E, main shoe wheel.
F, axle plate to ditto.
G, bracket to main shoe.
H, swing beam.
I, connecting rod.
K, crank wheel.
L, crank guard.
M, main frame.
N, whippletree bracket.
O, slide to ditto.
P, draught rod.
Q Q, travelling wheels.
R, ratchet pinion.
S, guard to spur wheel.
T, tipping lever.
U, lifting lever.
V, lifting quadrant.
W, lifting chain.
X, extension piece.
Y, seat.
Z, seat spring.
A1, pole bracket.
B1 B1, stays to swing beam.

The HAYMAKING MACHINE which superseded the hand fork for tossing and tedding hay consists of a number of tines mounted on heads attached by radial shafts to a revolving axle, driven at a considerable speed by gearing from the main driving wheels.

When the tines revolve in a direction opposed to the travel of the machine, the hay is tossed over the machine and spread out for drying. When they revolve in the opposite direction the partly-made hay is merely turned over, thereby exposing the underside to the sun and air (fig. 24).

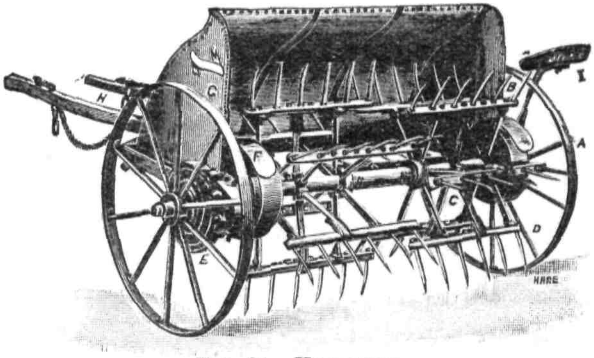


FIG. 24.—HAYMAKER.

A, road wheels.
B, tines or forks.
C, spring for fork-heads.
D, fork-head bar.
E, cover of gear box.
F, guards.
G, hood.
H, shafts.
I, seat.

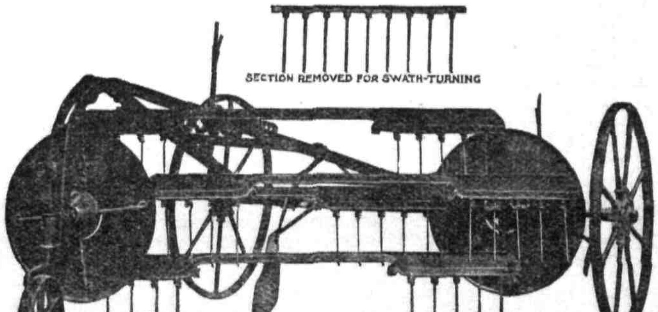


FIG. 25.—COMBINED SIDE RAKE, SWATHE TURNER, TEDDER AND WINDROWER.

The action of this machine under certain circumstances being considered too violent, the hay-kicker and swathe turner were evolved. The kicker consisted of a series of spring-tined forks connected to a crank axle which imparted a motion somewhat similar to that of a hand fork gently turning the hay (fig. 24).

The early swathe turners consisted of two interrupted helical discs with serrated edge (somewhat like a ship's propeller) mounted on two longitudinal spindles, the distance between which could be adjusted to suit the pitch of the swathes, these were driven by gearing from the main shaft, and in revolving they quietly turned over the partially dried swathe, exposing the underside.

The latest development at the present time is a combination "side rake," "swathe turner," "tedder," and "wind rower" (fig. 25).

The Horse-rake has long taken the place of the hand-rake and hand-drag for gathering grass and unsheaved corn into rows. The horse-rake consists of a light frame on two wheels (fig. 26). In the front of the machine are fitted a number of curved tines, extending the full width from wheel to wheel; these are so designed as to collect the material, and, on being raised up, to discharge it. The tines, which are made of steel, are adjustable, and, by altering the pitch of the machine, can be made to lightly skim, or closely rake the ground, as may be desired. By means of a ratchet gear, attached to the wheels, the work of raising and lowering the tines is, in the so-called 'self-acting' rakes, made to fall upon the horse, thus enabling boys or lads to work the implements. On these machines, the driver, who is provided with a seat, has only to guide the horse and to set free a pawl (or catch) by his foot, the horse doing the rest of the work.

These implements are also made with a lever for lifting the tines to discharge the collected material, and are easily worked by a man whilst riding on the seat, or when walking behind and holding the reins. A newer development of the Rake is the Side-Delivery Horse-rake, which delivers the collected crop in a continuous windrow.

The ELEVATOR, or STACKER (fig. 27), is used to carry hay, straw, or unthreshed corn on to the stack. When used for the stacking of material brought straight from the field, a pony-gear is often employed. When used for stacking straw from the threshing machine, it is set in motion by a strap running from a pulley on the

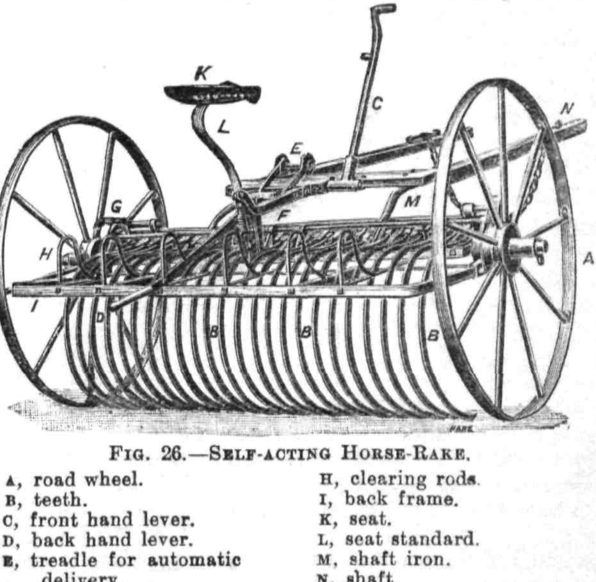


FIG. 26.—SELF-ACTING HORSE-RAKE.

A, road wheel.
B, teeth.
C, front hand lever.
D, back hand lever.
E, treadle for automatic delivery.
F, spring for lever.
G, pawl.
H, clearing rods.
I, back frame.
K, seat.
L, seat standard.
M, shaft iron.
N, shaft.

thresher. The elevator consists of a long trough, mounted on a frame supported by wheels. Endless chains, furnished with carrying prongs, placed at intervals of a few feet from each other, are made to travel up the trough, and to return over guiding pulleys underneath the trough. In this way the material is carried up in a continuous stream.

HAY AND STRAW PRESSES have lately come into general use. They compress light, bulky material into a small space, and thus render its transport less expensive.

These presses are made for working by hand, usually with two levers, with some form of mechanical device for raising and lowering the pressing platen. It is a useful plan for carting the material to market. **Steam-**

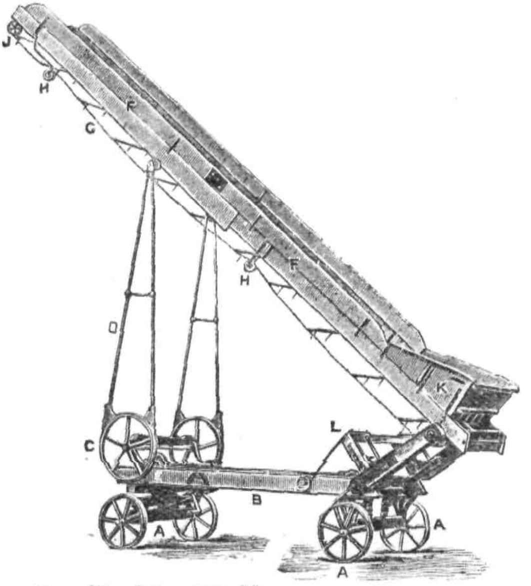


FIG. 27.—STACKING MACHINE OR ELEVATOR.

A, travelling wheels.
B, frame.
C, cogged wheels for raising the lifting rods, D.
E, worm screw for working lifting rods, D.
F, trough up which the material travels.
G, endless chain, with forks for carrying the material up the trough (seen returning beneath the trough).
H, guide pulley for endless chain.
J, adjustments for regulating endless chain.
K, hopper for receiving material to be stacked.
L, lifting gear for raising hopper. The hopper is shown *half-raised*. By raising the hopper, as required, the top end of the trough is kept continuously above the middle of the stack. Consequently, from beginning to end, the delivery takes place over the *middle* of the stack.

The Elevator is driven by a belt from a pulley on the Threshing Machine.

power perpetual presses make solid bales for railway transit or for shipment. The railways carry steam or hydraulic press bales at special rates. These presses are now made to work immediately behind the threshing machine, the straw passing direct from the shakers into the press, and thus saving the work of one or two men.

CARTS AND WAGGONS are indispensable accessories on a farm. Fig. 28 shows elevation and section of a cart wheel. The wheel is 'dished,' so that, when laid flat

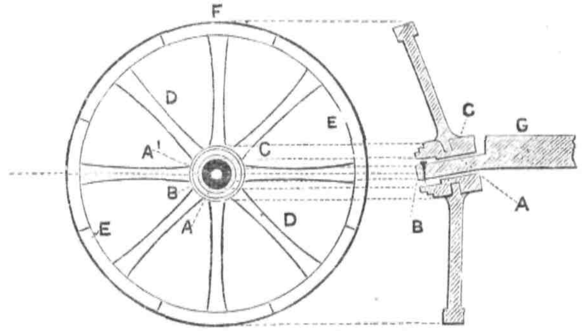


FIG. 28.—A CART WHEEL.

A, axle arm.
A¹, box (not required in iron-hubbed wheels).
B, linch-pin.
C, hub.
D, spokes.
E, felloes.
F, tire or ring.
G, axle.

on the ground, the rim is not on the same level as the solid centre. The axle-arm A is, moreover, bent in such a way that each spoke, as it comes between the arm and the ground, assumes the vertical position, which is that best adapted for bearing the weight of the load. Further support is derived from the circumstance that the outer end of the spoke rests upon the semicircular *arch* included in the tire.

Another effect of 'dishing' is that the dirt, which is dislodged from the part of the rim which happens to be at the highest position, falls outside the wheel, whilst there is no risk lest the rim should graze the side of the vehicle. The hub and the tire are the most

important parts of the wheel. So long as the tire lasts, any pressure transmitted through the spokes only serves to wedge the felloes more tightly together.

IMPLEMENTS FOR PREPARING CROPS FOR MARKET

THRESHING MACHINES. — The modern threshing machines (of one of which fig. 29 gives an external view, and fig. 30 a longitudinal vertical section) are all constructed to work on the same general principles, though a good deal of variation exists in the different machines with respect to the separation of the corn, etc. They are almost always driven by steam, but water power, oil-engines, and horse gears are occasionally used. A study of the longitudinal vertical section shown in fig. 30 will serve to indicate the course taken by the material in the operation of threshing, separating, and cleaning. The corn is fed into the drum-mouth U, where it is caught by the beaters A^1 of the drum A, and the grain is threshed out between these and the concave B. A large proportion of the grain falls through the concave, while that which remains with the straw is shaken out, together with short pieces of straw, chaff, etc., by the shakers, and falls upon the upper collecting tray E. The straw passes out of the machine over the shakers. All the material which passes through the concave and the shakers is conducted on to the floor of the upper shoe F, and then passed over the caving riddle F^1. The cavings (*i.e.*, refuse material intermediate between chaff and straw) pass over this riddle out of the machine, while the grain, chaff, and small refuse fall through on to the collecting tray G of the lower shoe. The separating action of the caving riddle is assisted by a blast of air through spout K^1 from the first fan K. The grain, chaff, and refuse are now taken into the lower shoe H, through which a blast of air from the first fan K is playing. The chaff is blown away, and the grain and heavier refuse fall through the chaff sieve H^1, on to the chob sieve H^2. The grain falls through this sieve, and the chobs (such as pieces of wood, small

stones, thistleheads, etc.) ride over an adjustable lip on to the ground. The grain from the sieve H^2 falls upon the seed sieve H^3, where any weed seeds or dust and

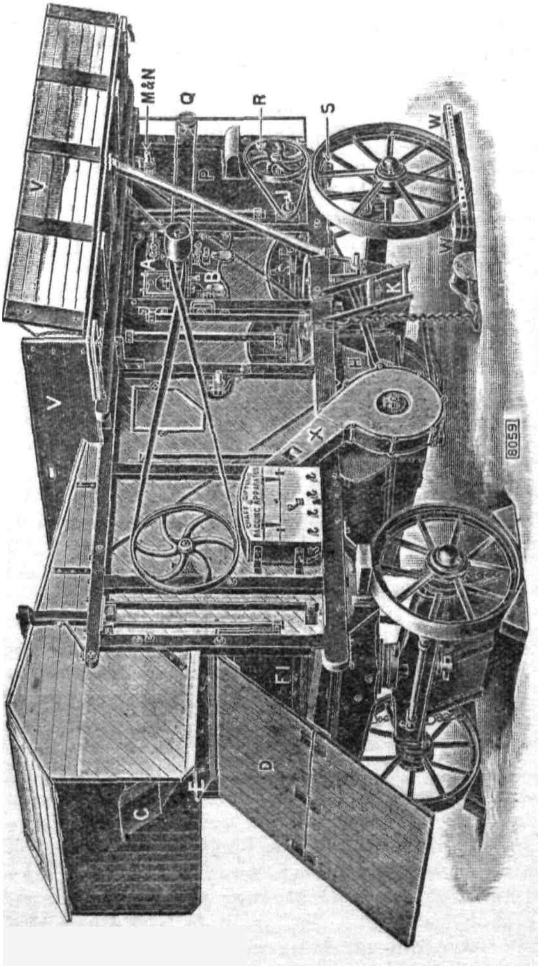


FIG. 29.—THRESHING MACHINE (NEAR SIDE).

A, threshing drum.
B, concave.
C, straw shakers.
D, straw board.
E, upper collecting tray.
F1, caving riddle.
H, lower jog shoe (1st dressing apps.)
J, crank for driving jog shoes.
K, first fan.
M, awner.
N, chobber.
P, 2nd dressing shoe.
Q, 2nd fan.
R, rotary corn screen.
S, corn spouts.
VV, guard boards round platform.
WW, wheel chocks.
X, chaff bagging apparatus.

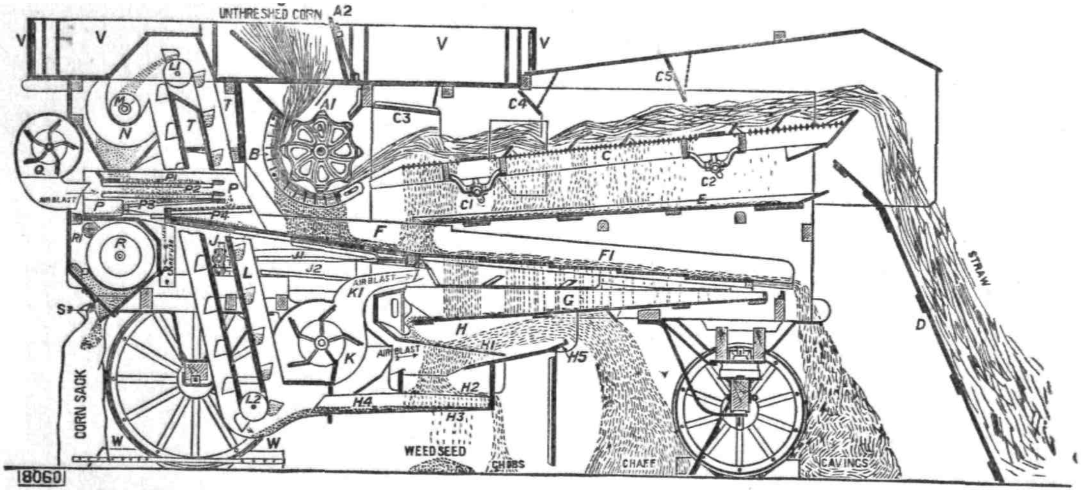


FIG. 30.—SECTION OF THRESHING MACHINE.—LONGITUDINAL VERTICAL SECTION.

A, threshing drum.
A1, beater.
A2, safety guard for drum mouth.
B, concave.
C, straw shakers.
C1, C2, cranks for straw shakers.
C3, dash board; C4, C5, check boards—(for arresting the grain.)
D, straw board.
E, upper collecting tray.
F, upper jog shoe.
F1, caving riddle.
G, collecting tray for lower shoe.
H, lower jog shoe (1st dressing apps.)
H1, chaff sieve.
H2, chob sieve.
H3, seed sieve.
H4, spout from lower shoe to grain elevator.
H5, adjustable tail board of lower shoe.
J, crank for driving jog shoes.
J1, J2, connecting rods.
K, 1st fan.
K1, blast spout.
L, grain elevator.
L1, L2, pulleys upon which the grain elevator works.
M, awner.
N, chobber.
P, 2nd dressing shoe.
P1, P2, grain sieves.
P3, seed sieves.
P4, refuse sieves.
P5, spout for seeds and refuse from 2nd dressing shoe.
Q, 2nd fan.
R, rotary corn screen.
R1, rotary corn screen brush.
S, corn spouts.
TT, manhole in which man stands to feed into mouth U.
U, drum mouth.
VVVV, guard boards around platform of machine.
WW, chocks for setting machine level.

sand are shaken out, while the grain passes along the spout H^4 to the elevator L. The grain elevator consists of buckets fastened to an endless belt working over the pulleys L^1 and L^2, and these buckets carry up the grain and deliver it into the awner and chobber M and N. Here the awns of barley and the white-heads, or tough unremoved chaff of the wheat are taken away. The chobber is adjustable, so that the grain may be subjected to more or less vigorous treatment, as desired. The grain now falls into the second dressing shoe P; there it passes through the grain sieves P^1 and P^2 on to seed sieve P^3. A blast of air from the second fan Q is directed through the second dressing shoe, and blows the light refuse back into the upper shoe. Material which rides over the sieves P^1 and P^2 falls upon the sieve P^4, through which any grain there may be present passes. The refuse passes over the sieve P^4 and falls down the spout P^5, with the seed and dust taken out of the now thoroughly cleaned grain by the sieve P^3. The grain is now taken to the rotary screen R, where it is graded. The rotary screen (for an example, see fig. 35) has helical bars running through it, so that the corn is carried from end to end, the thinnest grains passing through the divisions between the wire bars of the screen first; then a second and a third division are made by partitions placed in the hopper underneath. That which passes through the whole length of the screen is the dressed or finished sample. The screen may be adjusted to take out more or less small grains, as may be desired. In the general construction of the machine it will be noted that the collecting trays, spouts, etc., are inclined, but to keep the material steadily moving these inclined surfaces are given reciprocating motions, which are obtained by cranked shafts and wood springs, called suspenders.

To improve the quality of the dressing of the corn, and to increase the output, the area of the riddling and dressing surfaces has from time to time been increased and additional blast has been added.

Various accessories are now fitted to the modern threshing machine, among which the most generally used are the elevator driven by a belt from the threshing

machine, which delivers the straw from the shakers on to the stack. The chaff-sifting and lagging apparatus, etc.

Various accessories may now be fitted to the modern threshing machine, among which the most generally

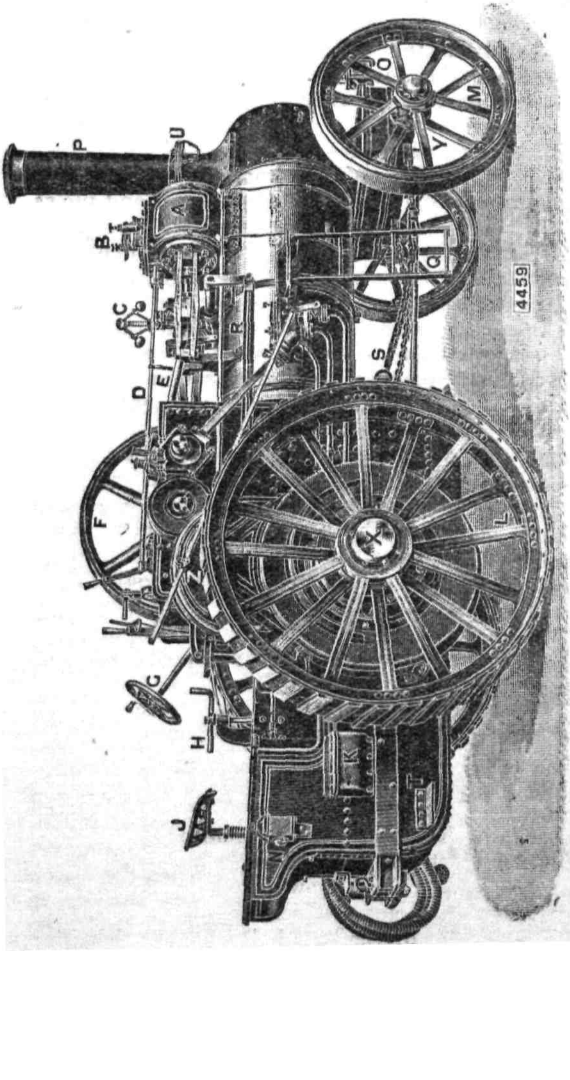


FIG. 31.—TRACTION ENGINE.

A, cylinder. B, safety valve. C, governor. D, regulator rod. E, connecting rod. F, fly wheel. G, steerage hand wheel. H, brake lever. J, steersman's seat. K, tank filler. L, driving wheel. M, leading wheel. N, tool box. O, lamp. P, chimney. Q, ladder. R, reversing rod. S, steering chains. T, tank. U, chimney joint. X, driving axle. Y, front axle. Z, wheel cover.

used are chaff sifting and bagging apparatus (one of which is shown fitted to the machine in fig. 29), and straw trusses for tying the straw into bundles as it is delivered from the shakers. This latter is a development of the sheaf binding apparatus of the harvesting machine.

STEAM ENGINES.—A view of a **farm locomotive,** or **traction engine,** which supplies steam power for threshing, hauling, sawing, and a variety of other purposes, is given in fig. 31. These locomotives are increasing in general use, and on many farms have taken the place of portable engines, which are drawn from place to place by horses, and which are so largely employed in all parts of the country.

Since their first introduction, the steam pressure has been considerably increased, the compound principle has been generally adopted except for very small powers, they have also been mounted on springs, both fore and aft wheels, all of which modifications have produced more efficient working and improved economy.

OIL ENGINES.—These convenient motors are now very largely used. They are specially valuable where work is intermittent, as is usually the case in a farmyard, as they can be started at a few minutes' notice, without the long delay involved in getting up steam, and are therefore particularly adapted for driving the different machines used in the preparation of food, such as chaff-cutting and gristing, and other light machines. Another advantage is that they do not require constant attention while running, as is the case with a steam engine. For stopping the engine, moreover, it is only necessary to turn off the supply of oil, so that there is little or no waste.

These engines usually run on what is known as the "Otto" cycle: a section is shown in fig. 32. The process of starting and working this engine is as follows: The vaporiser is raised to a dull red heat, by means of the coil lamp shown. The fly-wheel is now pulled round. This opens a valve, through which, as the piston moves forward, air is drawn into the cylinder. When the piston moves backward this valve is closed, and the air in the cylinder is compressed and forced through the

narrow neck at the back of the cylinder into the vaporiser. In the meantime the gearing has caused a small pump to send a jet of oil into the heated vaporiser. The hot walls of the vaporiser immediately convert the oil into vapour, and the compressed air forced in by the piston supplies heated oxygen sufficient to make a mixture that will cause the necessary explosion. The explosion thrusts out the piston, the products of combustion following it into the cylinder. On the return of the piston a valve is opened, and these products are forced into the exhaust pipe. With the next movement

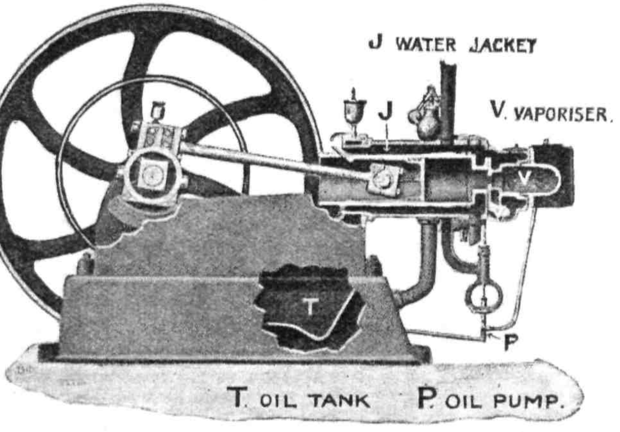


FIG. 32.—OIL ENGINE.

of the piston the cycle begins again. The heat generated by the explosion and the compression are sufficient to keep the vaporiser hot.

Where only a small amount of power is required PETROL ENGINES are sometimes used, and these are very convenient, starting as they do at a moment's notice, in the manner now so familiar in connection with motor cars; but it is doubtful whether such a highly inflammable liquid as petrol should be placed in unskilled hands, or in the vicinity of such combustible materials as are usually found in a farmyard.

WINNOWING MACHINES (fig. 33) are used for the further cleaning of the already partially cleaned corn, thereby rendering it more marketable. In the best machines, the winnower is strong enough to separate the light grains from the heavier, whilst smaller heavier seeds are removed by being passed over screens or riddles,

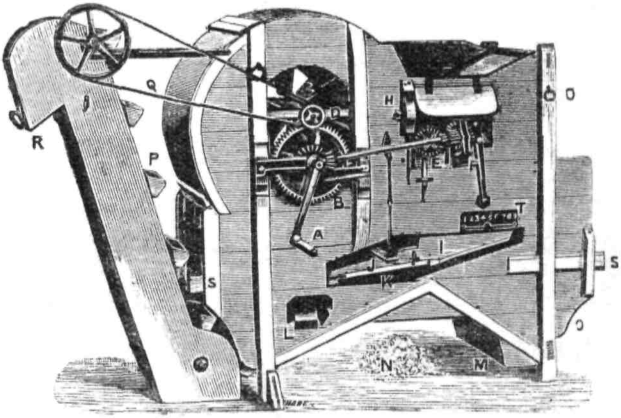


FIG. 33.—CORN WINNOWING OR DRESSING MACHINE.

A, handle.
B, main wheel.
C, fan.
D, pulley on fan axle to drive elevator.
E, wheel driving large roller.
F, wheel driving small roller.
G, hopper.
H, screw to regulate feed.
I, riddle frame.
J, riddle.
K, screen under riddle.
L, spout from which stones, sticks, &c., are delivered.
M, tailing corn.
N, screenings.
O, chaff.
P, elevator cups.
Q, strap to drive elevator.
R, spout where dressed corn is delivered into sacks.
S, lifting handles.

which contain the good grain and allow the impurities to fall through. Too many kinds of these machines are provided with a blast which, though strong enough to blow out chaff, is incompetent to separate the grains of different density. Such machines have to rely entirely on the screens for effecting the separation, which they do indifferently well.

Various SCREENS, such as the 'Boby,' and rotary screens, generally not fitted with a blast, are used with good effect (see figs. 34 and 35). The **rotary screen**

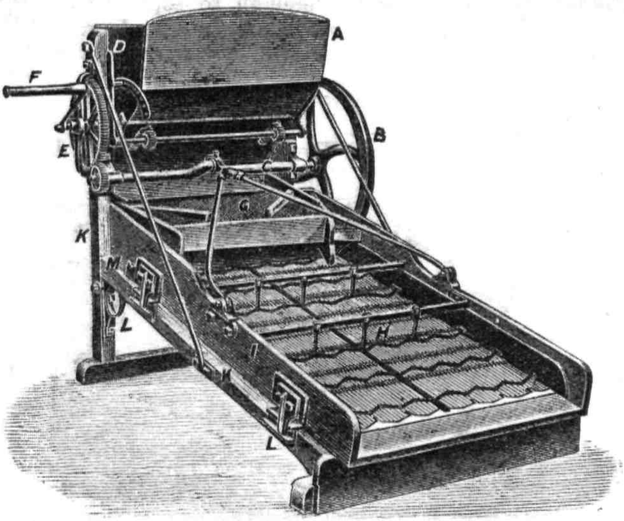


FIG. 34.—ADJUSTABLE FLAT CORN SCREEN.

A, hopper.
B, fly wheel.
C, crank.
D, lever for adjusting feed
E, gear wheel and pinion.
F, turning handle.
G, stone separator.
H, adjustable bed.
I, shoe frame.
K K, screen frame.
L L, rollers for shoe.
M, adjusting screw.

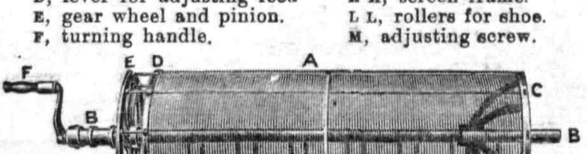


FIG. 35.—ADJUSTABLE ROTARY SCREEN.

A, screen barrel.
B B, hollow shaft containing adjusting screw.
C, feed end ring.
D, casting which slides along shaft.
E, fixed delivery ring.
F, handle for adjusting width between wires.
G, section of wire used in barrels.

(fig. 35) can be supported in any convenient frame, and the width of the spaces between the wires is graduated by means of the adjusting handle F and the screw in the hollow shaft, B B. The screen is turned by a handle fixed at the right-hand end, as seen in the diagram. Hand-sieves are usefully employed in conjunction with the other cleaning machines.

IMPLEMENTS FOR PREPARING FOOD FOR STOCK

CHAFF CUTTERS are used to cut hay and straw into short pieces, partly to aid mastication and digestion,

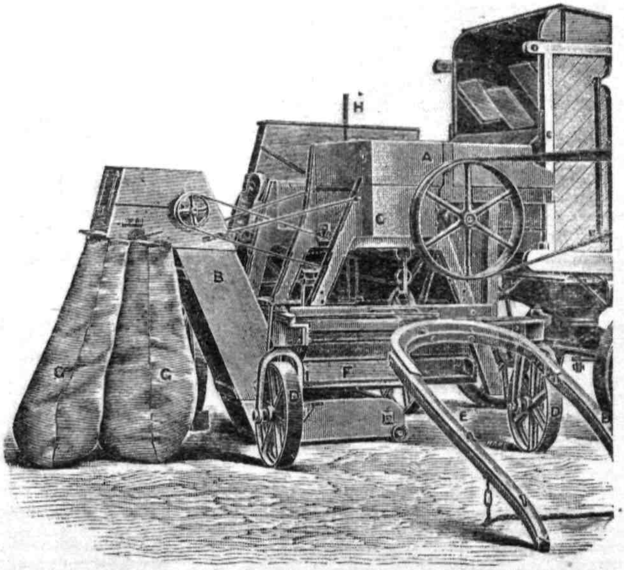


FIG. 36.—STEAM-POWER CHAFF-CUTTER, WITH SIFTING, DUSTING, AND BAGGING APPARATUS.

A, driving pulley, on which runs belt from thresher, or direct from engine.
B, elevator trough, or bagger.
C, end of feed box.
D, front travelling wheel.
E, shafts.
F, riddle for sifting out the imperfectly cut material.
G, chaff bags.
H, lever to stop and reverse the feed.

but more especially with a view to economy, as hay and straw are much wasted when they are given in the long state. Besides, it is possible to mix other foods, such as meal, cake, and roots, more economically when there is a bulky mass of short dry material to stir them among. Chaff is therefore generally looked upon as a vehicle for conveying these foods to animals, in addition to being a food in itself. Chaff cutters are made in all sizes, from small hand-worked implements up to powerful steam-driven machines (fig. 36) carrying half a dozen large knives, capable of cutting the straw into half-inch lengths as fast as it can be passed through the largest threshing machines. The material to be cut is placed in a long trough, and is drawn forward by means of cogged and fluted rollers to the knives. The latter are arranged radially on a fly-wheel, cutting from the centre outwards, and pass rapidly by the face or mouth of the feeding box. The arrangement of the knives is such that there is no intermission in the cutting, for as one knife is finishing its cut the next has already commenced to operate.

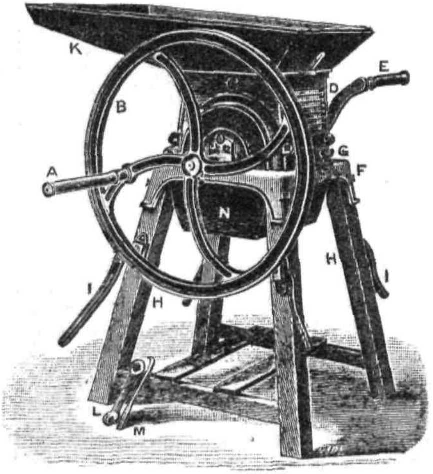


FIG. 37.—TURNIP-CUTTER.

A, handle.
B, fly-wheel.
C, iron body.
D, hopper grate.
E, auxiliary handle.
F, cast frame.
G, thumb screw.
H, wooden legs.
I, handles for carrying machine.
K, top hopper.
L, wrench, or spanner.
M, pricker.
N, bottom hopper.
O, adjustable bearings.

The larger machines are usually fitted with a riddling and a bagging apparatus, which sift out the dust and dirt from the chaff and elevate the latter into bags. All machines are now fitted with some form of safety device, to prevent the possibility of the attendant's hand being drawn with the hay, etc., between the rollers to the knives.

TURNIP-CUTTERS, or PULPERS (figs. 37 and 38), are usually made with a disc wheel fitted with knives of various forms, to produce slices, fingers, or pulp. Many machines are fitted with devices for removing earth or other foreign matter adhering to the roots.

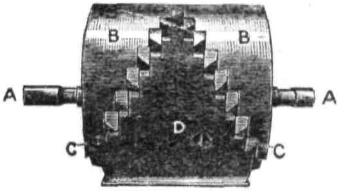


FIG. 38.—TURNIP-CUTTER BARREL.

A, spindle passing through centre of barrel.
B, steel plate.
C, acute-angled knives.
D, cast barrel to which the steel plates and knives are attached.

CORN GRINDING MILLS are made in several forms, perhaps the oldest being the Millstone, which has been used from time immemorial, and is still sometimes used on large farms. This form produces an excellent sample of meal, but at a considerable expenditure of time and power, and it is not well adapted to grinding the variety of produce that is generally used on a farm.

Mills with a pair of vertically mounted flat discs, with tangential grooves formed on their faces, are very largely used; they are very economical of power, and easily adapted to grinding a variety of produce, and are usually fitted with a spring arrangement, which permits of an increase of the space between the discs, to allow for the passage of hard foreign bodies through the mill without injury to the discs. The material to be ground is led into the centre and the meal escapes at the circumference.

Mills similar to the above, but with conoidal discs, are also made, and are very satisfactory.

Another form of mill that is largely used has a conical grooved roller, which revolves on a horizontal axle against a concave with similar grooves, the material to be ground being fed into the small end of the mill, and the meal escaping at the large end. These mills are economical of power, and easily adapted to various materials.

Roller Mills, with rollers either grooved or smooth, are largely used, and are specially adapted to crushing oats.

HAND IMPLEMENTS

Small implements are as necessary as the larger ones on farms, and are of still greater importance on allotments and small holdings, and especially in gardens.

The **spade** is used for breaking up the ground. It is forced into the soil by the pressure of the foot, and the earth, commonly called the *spit*, is lifted out and inverted, the result being much the same as in ploughing, but more thorough in character. The spade is held by the handle in the right hand, while the left hand grasps the heft lower down. The left foot is then applied, the spade is thrust into the ground, and the spit is lifted out and rapidly inverted by a sharp action of the wrist.

The **shovel** is very similar to the spade, but, as it is not used for breaking hard ground, it is made less rigid, whilst the sides are slightly turned up so as the better to hold loose material.

Forks.—The **3- and 4-tined forks** are used not only for digging ground, but for filling dung carts, and for spreading dung or other material upon the land. Those with short handles, similar to the handles of spades, are far superior to those with long handles, as they afford the workman much more power over the tool, and he is better able to use his wrist to give a sweeping stroke while spreading dung; at the same time they are more convenient for digging. The neck should curve sharply, thereby forming a crank which affords leverage, and thus aids the efforts of the workman.

Forks with two prongs or tines fixed into a long handle are often called **pitchforks.** The farmer applies the term pitchforks only to those which are made with specially long tines and handles, so as to render them convenient for raising or pitching hay and corn on to waggons or carts. The shorter ones are called emptying forks, as they are used for emptying the carts. A skilful workman uses his wrists very freely, whereas a novice uses them but slightly, and works clumsily and laboriously.

Caving forks, cocking or **pooking forks** (fig. 39) are shaped very much like dung forks, but have exceptionally long tines set widely apart, while there is a continuation of the tines behind the tread piece. The continuation extends several inches and then curves upwards and forwards, forming a scoop. They are particularly useful for collecting cavings, or for gathering together (or *pooking*) short barley into heaps ready for pitching.

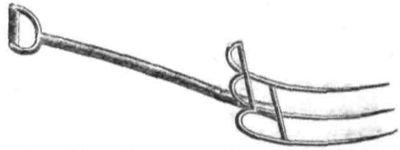


FIG. 39.—CAVING OR POOKING FORK.

Rakes are used for collecting short material, such as hay, and for levelling the surface of land before or after sowing seed. The best form of rake is made with a wooden head or crosspiece attached to a long handle, the head having inserted into it, at short intervals, small steel tines or teeth. This kind of rake is light enough for using in the hayfield, and strong enough for collecting couch or twitch, whilst it is very durable. The rake should not be used with a chopping or hoeing action, but should be so held that the handle rests gently in the left hand. The right hand should grasp the handle near the top, and the left hand lower down, the knuckles of both hands being turned downwards. The right hand should retain its hold firmly, but the rake should slide freely between the thumb and finger of the left hand. The wrists must be worked pliably, freedom of action being thus obtained.

Daisy rakes, with close-set wedge-shaped teeth, are frequently used on the farm for collecting the heads of Dutch clover when the crop is grown for seed.

Hoes are used for cutting up weeds in crops, and for loosening the surface of the soil in order to promote plant growth. The best form of hoe is (fig. 40) that fitted with a long curved or 'swan' neck. Any other mode of attaching the blade to the handle prevents the free use of the hoe on all except very clean, dry, and friable soils, as the weeds or earth clog, and thus hinder the workman in making a long stroke. Where other forms are used, it is only possible to make short chops, instead of long strokes. Hoes for use in wheat and barley crops should be from 4½ to 5½ in. in width; for peas, 6 to 8 in.; and for beans and root crops, 9 in. in width.

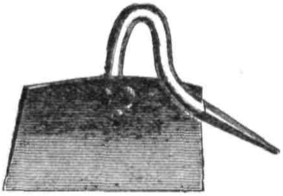


FIG. 40.—SWAN-NECK HOE.

Several forms of cutting tools are used for reaping and mowing corn. A few years ago there seemed great probability that large machines would totally supersede these, but since there has been an increase in the quantity of land let out in small holdings and allotments, the manufacture of small tools for harvesting purposes has revived.

The **scythe** consists of a long curved blade (fig. 41) fixed at something less than a right angle to the *snaith* or handle. The shape of the snaith varies in different localities, but the object aimed at is to make a snaith which permits the workman to swing the scythe with an easy curved sweep; for this reason perfectly straight handles are in many districts not used. The angle at which the blade is laid to the snaith has to be regulated according to the height of the workman and the nature of the crop to be mown. This is effected by means of large nails and strips of leather used for packing between the ring and the snaith.

The sward should be cut at the same height throughout. The ribbing often seen in fields after the crop is

cleared is evidence that the workman has not mown skilfully. The point of the blade should be laid in flat, and the stroke should be carried through completely to the end. If a man makes a scooping stroke he leaves perhaps a foot, at both the commencement and end of the stroke, which will have to be mown through, and for this reason it is very annoying for a good scytheman to have to follow a bad one. When mowing, the man should place his legs wide apart, so as to bring his back into the best position for it to exercise its strength, for mowing should be done by means of a body stroke rather than by the arms. The arms should act chiefly as guiding or connecting rods between the man and the scythe, in the same way as a skilful oarsman exerts his powers from the back, and by the use of his legs, instead of pulling the stroke through with his arms.

FIG. 41.—ENGLISH SCYTHE.

The early part of the stroke is easily made, as the natural swing of the scythe is sufficient to cut that section of the sward, but as material collects it becomes more difficult to complete the stroke, therefore the body must then be in a position to exert its force most freely. This is achieved when the man stands near to the finish of the stroke—*i.e.*, as far as practicable from the commencement. Young beginners make the end of the stroke with the left hand too far in advance of the left leg (which should be a little in the rear of the right). After the first half of the stroke the left hand should be drawn sharply round and near to the left leg. It is want of attention to this point which causes difficulty to beginners.

The whetting of the blade is an important detail in mowing. The whet-stone should be laid flat against the

blade, and drawn steadily along it. If the stone is not laid flat, an angle is made with the blade, the edge of which is rapidly lost, so that recourse to the grindstone is soon rendered necessary.

The **sickle** is the typical harvest tool, but is now rarely used on large farms. The sickle, or **reaping hook,** consists (fig. 42) of a short, curved blade, with finely serrated edges, and fixed into a short handle. **Reaping** is done thus:—The reaper grasps a handful of corn in his left hand at about a foot from the ground, and bends back the straws away from him. He next places the sickle behind the handful, so as to partly surround it, and draws the implement towards him, sawing the

FIG. 42.—SICKLE, South of England pattern.

FIG. 43.—BAGGING HOOK OR FAGGING HOOK.

straws asunder. The handful is then drawn out, and several such handfuls form a sheaf. The curve of the hook varies somewhat in different districts.

The **fagging hook,** or **bagging hook,** is used for cutting cereal and bean crops; also, when more strongly made, for cutting furze. The fagging hook (fig. 43) is very similar in shape to the sickle, but is made without a serrated edge. In some districts the blade is preferred slightly cranked near to the handle, whilst in others the crank is dispensed with. The cutting of the corn is effected by first chopping the stems, and then collecting them by means of the hook. The leg of the workman is used in gathering the sheaf, the corn being worked up against it. Fagging is a convenient way of cutting when the crop is badly laid. Reaping is more often practised when the corn is standing upright.

The **pea hook** (of which fig. 44 shows the blade and socket, the latter made to receive a wooden handle) is used for cutting peas. This crop lies about the land so much that mowing is impracticable, because many of the pods would be cut off and lost. The pea hook is in reality a short-bladed fagging hook set in a long handle, without any crank. Occasionally peas are cut with a short hook, but the work is then more laborious. An old sickle blade, with several inches of the pointed end broken off, is always highly valued for use as a pea hook, on account of the good 'temper' it has acquired.

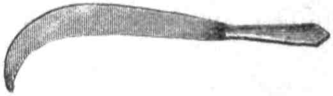


FIG. 44.—BEAN OR PEA HOOK.

FIG. 45.—SWITCH BILL OR SLASHER.

Hedge slashers and **switch bills** are formed (fig. 45) of a short stout blade fixed into a long strong handle. The blades, sometimes straight, are far more often slightly curved. They are used for trimming and laying, or layering, hedges.

CHAPTER VII.

TILLAGE

ONE of the primary conditions of success in farming is the proper and intelligent cultivation of the soil. By tillage we mean the ordinary processes of cultivation by which we stir the soil and prepare it for the reception of crops, so that they may flourish to the best advantage. To bring about the conditions necessary for the successful growth of crops the soil must be porous and in a fine state of division; it must be clean and free from weeds; and it must contain sufficient supplies of plant food and moisture. As a preparation for these

conditions the soil has to be loosened and turned over, so as to allow air, rain, frost, wind, and sunshine to exercise their pulverizing influence. This work is most effectually done by the spade or fork, and may be seen to best advantage in the garden. The earth, dug out to a depth of 8 or 9 inches, is thrown forward, thus leaving a trench, behind which fresh spits of mould are dug out and turned over. This method of hand cultivation is well suited to small areas, but where whole fields have to be dealt with, as on the farm, it is far too costly. Hence the farmer, having to cultivate extensive areas of land in a short time, has recourse to the plough. The plough and harrow perform in field culture the same operations as are far more thoroughly effected by the spade and rake in garden cultivation.

In preparing a **tilth** the ground is usually first of all turned over by the plough, and this is then followed by the cultivator, harrow, roll, and harrow, in the order named, the horse-hoe being used after the crop is up to stir the soil between the rows.

The operation of **ploughing** inverts the soil, burying manure, weeds, and any other vegetable growth, and exposes a large surface to the beneficial action of the weather. In the operation of **cultivating** the object is to stir and loosen the soil without actually inverting it, and the implements employed for the purpose are called **cultivators.**

Harrowing is carried out with the object of dragging out couch and other weeds previously uprooted so as to clean the land, and also for the purpose of reducing the surface to a fine condition after the other implements. The lighter harrows are also used for covering seed immediately after sowing.

Rolling breaks up the clods and gives a level surface to the land. It also consolidates the soil. Rolling the land in spring when it is dry has the effect of improving the capillary powers of the soil so that it is able to raise more moisture from below. This is a very important matter where young seeds are germinating in the ground.

Hoeing is carried out with the special object of destroying weeds, and it also stirs and loosens the soil. In dry weather keeping the hoe going between the rows of a growing crop and moving the soil to the depth of one or two inches makes a **mulch** on the surface which will tend to check evaporation of moisture from below, and convey it instead to the roots of the growing crop.

The plough and other implements of tillage have been described in detail in the preceding chapter, where their various forms and different methods of use are explained.

Tillage operations are most conveniently discussed under the headings of autumn, winter, spring, and summer work, according to the time of the year the preparations for the various crops are most actively carried out.

Autumn Cultivation.—In the late summer and early autumn the clover and 'seed' leys are generally ploughed, in preparation for the succeeding wheat crop, together with any land intended for winter beans and vetches; a coating of dung being applied previously where necessary. In the case of wheat on the lighter soils the furrow when turned is usually furrow-pressed or rolled, and the seed is then either sown broadcast and harrowed in, or the soil is first worked down with the drags and harrows, the seed being subsequently drilled and covered with a double stroke of the harrow.

The most important part of autumn cultivation, however, consists, when the weather is favourable, of breaking up the stubbles and making an attempt to remove a coating of couch and other weeds in preparation for next year's fallow crops.

Winter beans are generally grown on the stronger soils, and it is advisable to put them in as soon after harvest as possible, so that they may be well established before winter. This crop, as a rule, follows oats or barley, and the seed can either be ploughed in—a small drill or hopper being attached to every second or third plough for the purpose—or, after ploughing, the furrow

can be harrowed down and the beans then drilled and harrowed in.

Other crops sown in the early autumn are winter rye, winter oats, and winter barley, the cultivation required for these being simple, as in the case of wheat Thus the land is ploughed and the seed is sown broadcast on the furrow, or the furrow is first harrowed down and the seed then drilled, in both cases the seed being subsequently harrowed in.

Winter Cultivation.—Towards the end of the year and during winter the principal work consists in ploughing. The land intended for roots, and which, under favourable circumstances, has been subjected to a series of cleaning operations during the autumn, is deeply ploughed, so as expose the furrow to the ameliorating effects of the weather for as long a period as possible before moving it again. Winter ploughing also includes turning over the stubbles and other land intended for spring corn, and breaking up the ground which has been fed off after roots with sheep.

Spring Cultivation.—In the spring from February onwards an active period of work commences on the farm, including the actual preparation of the tilths for and drilling of spring corn, the cross-ploughing and cultivating of the root fallows, and a continuation of breaking up the land after the sheep folds, where this has not already been accomplished. There is a great demand for horse labour on the farm at this period of the year, and consequently the endurance of the teams is greatly taxed.

The mangel fallows next call for attention, and the land, which should have been cleaned and ploughed early for this purpose, must be worked down to a deep mellow tilth, being fine underneath, but firm at the time of sowing.

Cleaning operations may also be necessary, especially if the weather of the preceding autumn was unfavourable for the purpose, on the root-fallows intended for swedes and turnips; and as summer advances the seed beds for these crops must be prepared. The actual preparation of these tilths is often a matter of some

anxiety, and calls for much skill and experience on the part of the cultivator; and the order in which the various implements, particularly the harrow and the roller, should follow one another at the finish often requires great nicety of judgment to decide.

Summer Cultivation.—On the heaviest soils a **bare** or **dead fallow** is sometimes taken during the summer, although the practice is not nearly so common now as it was formerly, and much of the land of this description has gone out of cultivation, or been laid down to grass. Where the system is still followed frequent ploughings and stirrings are given, so that the large clods on the surface are moved about and thoroughly baked under the influence of the sun's heat, and thus the couch and other weeds contained in them are destroyed. The exposure to the sun and rain, with alternate baking and moistening, causes the clods to gradually shatter, and in this way towards autumn a tilth composed of fine particles and small clods is obtained, which is very suitable as a seed bed for the succeeding wheat crop. Another important operation carried out during the summer months is the process of 'intertillage,' or hand-hoeing and horse-hoeing between the root and certain other crops, so as to destroy weeds and stir the first few inches of the soil.

To explain **the best method of obtaining a tilth and cleaning a field,** it will be advisable to take the case of a wheat stubble which is foul with couch, and intended to carry a crop of swedes the following year. After harvest, if the weather is favourable, the first thing to do is to pare the stubble shallowly either with the paring ploughs or broad shares, so that a section of some two inches in depth is removed from the surface. Or, if steam cultivators are available, they may be set to work to break up the stubble, working it in two directions at right angles to one another. Whatever implement is used the object is the same,—to detach a thin layer of soil from the surface, which is afterwards worked with the drags to further disintegrate it. It is then generally rolled, harrowed several times with medium harrows to separate out the couch and weeds

LIBRARY

and the rubbish thus drawn out is afterwards collected on the surface with chain harrows. The couch and other refuse is then burnt in small heaps and the ashes spread. The number of times the various implements will have to be used to effect the above purpose will depend to a large extent on the circumstances of each case, and also on the condition of the soil. If the weather still holds fine a second series of operations may be advisable, commencing again with ploughing, and following with the other implements, so as to remove a further coating of couch and weeds. Even a third set of cleaning operations may be necessary where there are very foul spots in the field. The next thing, provided the soil is fairly retentive, is to apply a good dressing of dung, where this is available, and have it spread on the surface, and then follow by giving the land a ploughing as deep as possible according to the nature of the soil.

This ploughing is called 'winter ploughing,' because it exposes the furrow to the pulverizing effects of atmospheric agents during the winter months, so that it becomes well shattered before it is moved again in the new year.

In the early spring, if the land is clean, it may only be necessary to work the furrows across at right angles with the cultivator, so as to break them down, and thus obtain a suitable mixture of clods and finer particles, which can afterwards be further reduced with the lighter implements when preparing the actual seed beds. These conditions, however, are not always obtained in practice, and in the majority of cases, where the soil has settled down and run together, it will be found necessary to cross-plough it in the spring, and in some cases a third ploughing is essential before a suitable tilth can be obtained for sowing. It is a mistake to plough again in spring if it can possibly be avoided, as, in the case of heavy soils, the fine surface tilth which has been obtained by the winter's frost is lost; while turning over light soils in spring, especially in dry weather, allows the drought to enter, and causes them to become too loose and open.

In cases where it has not been possible to carry out

autumn cultivation, and the land is very foul, it will be necessary to conduct a series of cleaning operations in the spring, even at the risk of losing the winter's tilth, or letting the drought into the soil. A way in which it is easy to make a mistake in spring cultivation is when the winter furrow is first broken up, and there are a number of large clods below the surface, to try and force a tilth on the top by means of the roller and harrow. If this is done the soil will be too dry and open below, and unsatisfactory results will be obtained at seed time. After moving the winter furrow, time should be allowed for the larger clods to be exposed to the weather, and the soil should not be worked again till it is in a suitable condition, when drags and the cultivator will further reduce it, producing a mass of fine particles underneath with a layer of coarser fragments on the surface. After this the harrow and roller will prepare the actual seed bed, consisting of a deep, mellow, firm tilth, composed of fine mould, on the surface of which is a layer of small clods, which will act as a mulch.

A **good tilth** may be recognized by its smooth, even surface, which is comfortable to walk on, and sufficiently firm to prevent one from sinking into it. The soil should be worked to an even depth all over the field, and a stick pushed in should sink to the same depth at any point. When moved, a fine mould should be found below the surface, free from any large clods, and containing sufficient moisture for the germination of seed.

The land should be clean and the surface free from annual weeds.

There are some **main differences between the cultivation of heavy and light soils.**

Clay soils must never be worked when wet, for if this is done the particles tend to run together, and afterwards to bake into hard lumps, which it will be almost impossible to bring down again into a suitable tilth.

Ploughing at the proper time and making use of the forces of nature by exposing the soil to the disintegrating effects of the weather, especially frost during

the winter, are the best means of breaking down a clay soil and obtaining a suitable tilth in the spring.

Exposure to changes of temperature in summer, so that the clods are alternately baked by the sun and then moistened by rain, will cause them to shatter and come down into a fine condition.

Autumn cultivation is specially suitable for clay soils, as the land then is in its best condition for working, and can afterwards be left exposed for the winter.

Clay soils are naturally firm and close in texture, and the aim of the cultivator should be to lighten them up as much as possible, and this can be done to a certain extent by the application of dung in a 'long' or fresh condition, and the ploughing in of any vegetable refuse which will take some time to decay. Lime also has a beneficial effect in improving the texture of clay soils.

In dealing with **light soils,** on the other hand, the main object is to get them firm and sufficiently consolidated. For this reason sheep are almost indispensable to the light land farmer, for, besides manuring the land where they are folded, they also consolidate it by the even and regular treading of their small hoofs.

Light soils very easily dry out, especially in the spring time, and it is therefore a mistake to over-cultivate them at this season of the year, as drought is liable to get in, rendering them too dry for seeding purposes. Cleaning operations carried out too late in the spring should also be avoided for the same reason.

Farmyard manure on light soils should be applied in a well-rotted condition, as long, strawy dung would render the soil too light or 'hover,' and also tend to let in the drought.

After cultivation, or **inter-tillage,** refers to work that is carried out after the crop is sown. Thus wheat is generally harrowed and rolled in spring, with the object of breaking the crust which often forms on the surface during winter, and also consolidating the soil round the roots of the young plants. Barley and oats are sometimes treated in a similar manner.

The **hoe** and the **horse-hoe** are the principal implements, however, used in after-cultivation, and they

must be kept going among the root crops throughout the summer till the plants become too large in the rows to allow their passage. It was Jethro Tull, a Berkshire landowner, farming at the beginning of the eighteenth century, who introduced one of the most important improvements ever made in agriculture by growing crops in rows, so that the soil could be stirred between them. The advantages of this method were afterwards recognized, and led to a revolution in husbandry practices, so that it became possible to grow large crops of roots, providing abundance of succulent food for stock during the winter.

The beneficial effects of moving the soil between the rows of a growing crop are, therefore: (1) to destroy weeds; (2) to break up any pan and to allow the air to enter the soil; and (3) to form a mulch on the surface which will retain the moisture rising from below.

From the above we see that the chief **objects of tillage** are therefore :—

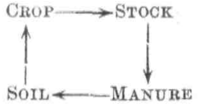
1. To clean the land by dragging out and destroying couch and other weeds growing therein.
2. To expose the soil particles to the disintegrating action of the weather, thus obtaining a suitable tilth for the germination of seed, and the development of a healthy root system.
3. To break up the soil and improve its mechanical texture, whereby the movements of air and water within it will be assisted. The process of rendering soluble some of the dormant plant food present will also be hastened.
4. To bury farmyard manure together with stubble and any vegetable rubbish on the surface so that it may decay and add to the stock of organic matter in the soil.
5. To destroy insect pests.

CHAPTER VIII.

MANURES AND MANURING

THE system of manuring by means of stock is the backbone of farming. The animals are either fed on the land, or the manure from the steadings is spread upon the fields. The land is thus manured through the stock,

and the nature and quality of the food supplied to the stock, equally with the character of the stock that are fed, will have a direct influence upon the value of the manure. The relationship between soil and stock is conveniently indicated in the subjoined diagram:—



Only a portion of the food that an animal receives enters into the composition of its body. A considerable proportion is consumed in maintaining the heat of the body, and is lost, in the form of carbon dioxide and water vapour, from the lungs and the skin.

The remainder, including the greater part of the nitrogenous and mineral matter, passes from the animal in the form of solid and liquid excrement, and it is these which are capable of being returned with much benefit to the soil. In former days, when no manufactured feeding stuffs or artificial manures were purchased, the fertility of the soil was kept up solely by means of this refuse matter, and it was to avoid rapid exhaustion of the soil that tenants were bound in their leases not to sell any hay, or straw, or roots, but to consume these on the farm, in order that most of the mineral and nitrogenous matter they took from the land might be returned to it.

When cattle or sheep are grazed upon the land, their excreta fall at once upon the soil, so that more useful matter is thus recovered than when food is consumed in the farmyard. In the latter case various sources of loss arise before the manure reaches the land.

Young growing animals are building up their muscles and bones. Hence they extract more nitrogen and phosphorus from their food than is the case with adult animals whose increase in weight is chiefly of fat. As fat contains neither nitrogen nor phosphorus, the manure of grown-up fatting animals is more valuable than that of young growing stock.

In the same way, cows in calf, or cows in milk, make a demand upon the nitrogen, phosphorus, and potash of the food, such as does not arise in the case of oxen or barren cows, and the manure is the poorer through the absence of those ingredients which go to build up the calf or to form the milk.

FARMYARD MANURE

Where cattle are fed at the homesteads, as on arable farms, and even on grazing farms at certain periods of the year, their excreta take the form of **farmyard manure**, or 'dung.' This consists of the straw or other material supplied to the animals as litter, mixed with

TABLE XVI.—CHEMICAL COMPOSITION OF FARMYARD MANURE.*

Water ...	75·42
[1] Organic matter	16·52
Oxide of iron and alumina ...	·36
Lime ...	2·28
Magnesia	·14
Potash ...	·48
Soda ...	·08
[2] Phosphoric acid	·44
Sulphuric acid	·12
Chlorine	·02
Carbonic acid, etc.	1·38
Silica ...	2·76
	100·00
[1] Containing nitrogen...	·59
equal to ammonia ...	·72
[2] equal to phosphate of lime ...	·96

or generally, 65 to 80 per cent. water, ·45 to ·65 per cent. nitrogen, ·4 to ·8 per cent. potash, and ·2 to ·5 per cent. phosphoric acid.

their solid excreta, and saturated with their urine, the whole trodden into a more or less compact mass. As this dung contains a large proportion of the manurial matter yielded by crops grown on the farm, as well as

* This is a good average (taken from the Woburn Experiments) of well made farmyard manure, produced by bullocks in feeding boxes receiving cake and corn.

by purchased foods, it is a precious material, and is the chief mainstay of the fertility of the farm. Much, therefore, depends upon the skill with which a farmer manages this product.

Farmyard manure is distinguished by the fact that *it contains* **all the constituents** which the land requires in order to grow crops. Of inorganic ingredients it possesses potash, soda, lime, magnesia, oxide of iron, silica, chlorine, phosphoric acid, and carbonic acid, all of which are found in the ashes of crops. The organic constituents are represented by various nitrogenous compounds which give rise to ammonia and humic acids, the latter forming a considerable part of the dark-coloured vegetable material, or humus, from which, by means of nitrification, nitrogen is supplied to growing crops. The complexity of its composition helps to render farmyard manure a perfect, as well as **a general manure.**

The average composition of the solid and liquid excreta of farm animals, as shown in the following table (from A. D. Hall), is worth noting:—

TABLE XVII.—PERCENTAGE COMPOSITION OF EXCRETA.

Animal	Excreta.	Water.	Nitrogen.	Phosphoric acid.	Potash.
Horse ...	Solid ...	75·0	0·56	0·35	0·1
	Liquid ...	90·0	1·52	trace	0·92
Cow ...	Solid ...	86·0	0·44	0·12	0·04
	Liquid ...	91·5	1·05	trace	1·36
Sheep ...	Solid ...	57·6	0·72	0·44	—
	Liquid ...	86·5	1·31	0·01	—
Pig ...	Solid ...	76·0	0·48	0·58	0·36
	Liquid ...	97·6	0·50	0·14	0·70

The solid excreta chiefly contain phosphoric acid, lime, magnesia, and silica, with comparatively little nitrogen. The liquid excreta, on the other hand, are almost destitute of phosphoric acid, but abound in alkaline salts (including potash), and in nitrogenous

organic matters, including urea and uric acid, which yield ammonia on decomposition.

These facts show clearly that the most valuable constituents of dung are contained in the urine of live stock. The straw or other litter absorbs this liquid, though some of it is liable to drain away unless a large quantity of litter is employed. A loss thus arises, and a still greater loss is incurred if, in the course of the fermentation of dung, a dark brown liquor is allowed to trickle from the mass. This liquor contains not only the constituents of the urine, but the valuable solid matter which has become soluble.

As straw will absorb any ordinary liquids, an endeavour should be made to restrict its absorbent powers entirely to the excreta of the animals, and for this purpose the litter should be kept out of reach of rain or other water. The washing out from the manure of its fertilizing ingredients will at the same time be prevented. For the better preservation of dung, therefore, **covered yards** have been devised. A portion of the farmyard is covered with roofing, and though this involves considerable expenditure at the outset, the cost is found to more than repay itself in the better quality of the manure. In a covered yard the floor and gutters can be so disposed as to cause drainings from the heap and urine from the cattle byres to flow into a tank, whence the liquid may be taken as occasion requires, or else pumped back on to the heap. Tanks are sometimes provided in open yards.

An advantage of a covered yard is that dung may accumulate in it to a considerable depth, beneath the treading of the stock, which helps to make the mass uniform in texture and quality. The use of roughly chaffed straw and peatmoss litter will aid in the formation of a well-consolidated bed of dung.

Sooner or later, the manure—unless for special reasons put upon the land at once—finds its way to the 'dung-heap,' though this will happen more frequently in the case of an open yard. In the **dung heap** two sources of loss have to be guarded against—**drainage** and **excessive fermentation.**

Fermentation is the name given to those chemical changes, brought about by the action of bacteria, which result in making the manure 'ripe' or 'mellow,' and better adapted to the immediate use of growing plants. It is a process of oxidation, and can only take place where there is free access of air. Heat is produced by the union of oxygen with the ingredients of the dung, and the more rapid the fermentation the greater is the heat. It is obvious then that fermentation may be controlled by increasing or diminishing the quantity of air that gains access to the heap, the oxidation being most active when the manure lies loosely, and least so when the heap is compressed.

Most of the nitrogen in urine is present in the form of a compound called **urea,** which, in the course of fermentation, is altered into carbonate of ammonia. This, being a volatile substance, passes off into the air, and a serious loss to the manure heap of its most valuable element, nitrogen, may thus occur Even free nitrogen gas may pass off, if the heap becomes too dry. In such cases the compression and moistening of the heap are desirable.

The losses in making and storing farmyard manure have been found, as the outcome of a number of experiments spread over different years at the Woburn Experimental Farm, to be, on an average, 15 per cent. of the total nitrogen of the food used during the making of the dung, and 19 per cent. more (making 34 per cent. in all) in storing. As this applies to the most favourable conditions, the loss, under ordinary circumstances, must be put at 50 per cent. of the nitrogen of the food, and this is the figure adopted by Lawes and Gilbert in their tables.

Unfermented dung is known as 'fresh' or 'long' manure, the straw in it having undergone little alteration. Well **fermented dung** is termed 'rotten' or 'short' manure. Rotten is more concentrated than fresh manure, and contains a larger proportion of soluble ingredients, for which reason it is more immediately available as plant-food.

It is characteristic of farmyard manure to leave in the soil a large, though **slowly available residue** of food at the disposal of future crops. It is the nitrogen of the liquid excreta of animals that is first rendered useful to plants within the soil, then that of the finely divided matter which passes intermixed with some secretions in the solid excrements, and lastly that of the litter.

The **physical effect of farmyard manure** upon soils is as important as its chemical influence. The general rule according to which short and well-rotted dung is applied to light open soils, and long fresh dung to heavy compact soils, is one intimately associated with the mutual physical relations of soil and manure. The fresher the dung the less ready are its constituents to enter into combinations available as plant-food; and in this form a stiff clay soil is well adapted to hold or retain it till the occurrence of those chemical reactions which result in rendering the nutrient ingredients of the manure presentable to the plant. The older and the more rotted the dung, before application, the more promptly are its fertilizing ingredients available; and, as light porous soils are deficient in retentive power, it is well they should receive dung in an advanced state of decomposition, and at a time when the crop is ready to make use of it, loss of manurial substance by means of the drainage waters being thus avoided. Furthermore, long or green manure helps to open up stiff soils; and the fresh straw provides air channels along which the atmosphere can find its way into the interstices of the soil, oxidation being thereby promoted. Conversely, the application of short or much-decomposed dung to a light or sandy soil has the beneficial effect of making it firmer and of rendering it less rapidly permeable by water.

ARTIFICIAL MANURES

Of the essential constituents of their food which cultivated plants obtain from the soil, it has been stated (p. 19) that those which are liable to become temporarily exhausted include nitrogen, phosphoric acid, potash,

and lime. It is chiefly with the object of supplying any deficiency in one or more of these—particularly of the first three—that manuring is resorted to, though, even in this case, the main source of these substances is still to be sought in the store of **fertility** which has accumulated in most cultivable soils. It is partly for the privilege of drawing upon this reservoir of plant-food that the tenant farmer pays rent to his landlord. Year by year the soil doles out from its vast stores of insoluble matter small quantities dissolved in water, and therefore available as the food of crops, and to these the farmer adds contributions of his own in the form of natural and artificial fertilizers. The latter help to maintain the **condition** of the soil, as distinguished from its fertility. It is quite possible for a soil of low natural fertility to be brought into a high condition. It is the natural fertility inherent in a soil which is given in exchange for rent, whilst the 'condition' depends upon the additional fertility which the tenant brings upon the land at his option.

Artificial manures possess the advantage of presenting a large quantity of fertilizing material in a small bulk. They were formerly described as portable manures, because, as compared with farmyard manure, they are easily carried from place to place. In other words, the carriage of a given quantity of nitrogen, or of phosphorus, from one place to another would cost far less in the form of an artificial fertilizer than in that of farmyard manure. Some artificial fertilizers contain only one valuable ingredient, and are then spoken of as nitrogenous, phosphatic, or potash manures, as the case may be; others, such as Peruvian guano, contain more than one.

Peruvian guano is the excrement of fish-eating sea-birds which has accumulated in the rainless districts of Peru. In former years it was a rich ammoniacal manure, but as the best deposits have been worked out its character has altered, and it is now richer in phosphates and poorer in nitrogen. The higher qualities still obtainable yield from 8 to 10 or 12 per cent. of ammonia, and the poorer grades only about 4 per cent.,

and even less, with, however, from 30 to 50 per cent. of phosphates. The better qualities, when available, are a valuable top-dressing for corn crops. The lower qualities are cheap enough to be used for any of the purposes to which fine bone-meal is applied. The lower class guanos are the residues left after the more soluble ingredients of high-class guanos have been washed out by rain. From 1 to 3 per cent. of potash may be present, besides a variable proportion of insoluble stony matter, derived from the rock on which the guano is deposited. After having been driven away, the birds are now returning to some of the islands, where they are forming fresh supplies of guano.

Fish guano is rather inappropriately named, as it is not a real guano. It is obtained from fish-curing establishments, and consists of fish offal, sometimes of whole fish, dried and ground. Fish guanos, according to their source, yield from 6 to 10 per cent. of ammonia, and from 10 to 15 per cent., or even more, of phosphate of lime. More correctly speaking, there are two kinds of this fertilizer; one with a high percentage (10 to 11) of nitrogen, and a low percentage (11 to 15) of phosphate of lime; the other with a low nitrogen percentage (5 to 6), and a high percentage (30 to 40) of phosphate of lime. Fish guanos often contain fish-oil, which renders them less serviceable as manures, because it delays decomposition.

Bones are essentially a phosphatic manure, though they also yield a certain amount of nitrogen. The quality depends upon the treatment of the bones before their application to the soil. Coarsely **crushed bones** decompose but slowly, and occupy some years in yielding up their fertilizing ingredients. **Raw bone-meal** of good quality contains from 45 to 50 per cent. of phosphate of lime, with nitrogen equal to 4½ or 5 per cent. of ammonia. The more finely-ground the meal the more speedy is its action. Bones that have been **steamed at** high pressure, to deprive them of the gelatine used in glue-making, contain much more phosphate of lime (55 to 65 per cent.), but nitrogen equal to only about 1½ or 2 per cent. of ammonia; these steamed bones

are often ground into a fine flour before use. Bones are chiefly used as a manure for turnips and swedes, and for top-dressing pasture land. Table XVIII. gives analyses of average samples of bone-meal and steamed bone.

TABLE XVIII.—*Composition of average samples of* BONE-MEAL *and* STEAMED BONE.

	Bone-meal.	Steamed bone.
Moisture	10·43	12·41
[1] Organic matter	32·30	15·07
Phosphate of lime	48·40	61·17
Carbonate of lime, magnesia, etc.	7·20	10·17
Insoluble siliceous matter	1·67	1·18
	100·00	100·00
[1] Containing nitrogen	3·71	1·08
Equal to ammonia	4·51	1·31

To hasten the action of bones, and so to get a more prompt return from their application to the land, Liebig proposed that they should be treated with sulphuric acid. The result is that the insoluble (tribasic) phosphate of lime which they contain is converted into a new compound of phosphoric acid, which readily dissolves in water.* Dissolved bones are thus produced. Peruvian guano is similarly 'dissolved' by means of sulphuric acid, and to it sulphate of ammonia is frequently added, thus producing a strong active manure.

It was found that the same process could be successfully applied to mineral phosphates, the resulting soluble compound being called a **mineral superphosphate,** to distinguish it from the **dissolved bones** which have just been referred to. Attention was first turned

* The term 'superphosphate' is applied to this compound and the calcium sulphate, etc., with which it is mixed (*see* TABLE XIX.). It does not imply, as might be supposed, that an unusually large amount of phosphoric acid is present.

to mineral phosphates when it was realized (about 1840) that bones owed their value as a manure to the presence of phosphate of lime. The minerals known as apatite and phosphorite first received attention, and material of the kind imported from Estremadura (Spain) was used in 1843 for field trials in England. Apatite from Canada and Norway has also been employed to some extent. An important advance followed the discovery in 1845 of phosphatic nodules known as 'coprolites' in the Cambridge greensand. These were extensively worked, as were similar deposits in the Crag. Competition with foreign phosphates of similar nature, but occurring in larger quantity, ultimately ruined the native industry. The phosphates of Lahn (Germany) were largely worked for some time, but contain too great a proportion of oxide of iron and alumina. The objection to the Belgian phosphates from near Mons is the low percentage (40 to 50) of phosphate of lime. The Somme phosphates from North France are superior to both the preceding, containing, as they do, but little (1 to 2 per cent.) oxide of iron and alumina, and a large amount (up to 70 per cent.) of phosphate of lime. Florida phosphate, containing 70 to 78 per cent. of phosphate of lime, and very free from the oxides mentioned, is of still greater value, but the most important source of this kind of mineral matter is now North Africa. There is here an important deposit at the base of the Eocene, and extensively mined in Algeria and Tunis. It probably exists in Morocco, and is found in Egypt, though it is there of less value than in the first-named countries, where it contains from 55 to 65 per cent. of phosphate, without much iron or alumina.

Mention must also be made of the 'crust' guanos, from which the nitrogen has been almost or entirely washed out. These are chiefly found in the West Indies (Sombrero, Curaçoa), the Pacific (Ocean and Christmas Islands), and Bolivia. The Christmas and Ocean Islands' deposits, containing 80 to 86 per cent. of phosphate are the most important ones now worked.

In manufacturing superphosphate the raw materials are finely ground, and then treated with dilute oil of

vitriol (sulphuric acid), which results in the production of monobasic (soluble) phosphate of lime and sulphate of lime. The oxides of iron and alumina present in some of the mineral phosphates are undesirable, because they interfere with a proper mechanical condition of the manufactured product, and also lead to 'reversion,' *i.e.*, the conversion of soluble phosphate into insoluble or 'reverted' phosphate (intermediate di-calcium phosphate). There is consequently a certain amount of deterioration during storage. Analyses are given in Table XIX.

TABLE XIX.—*Composition of average samples of* MINERAL SUPERPHOSPHATE OF LIME *and pure* DISSOLVED BONES.

	Mineral super-phosphate of lime.	Pure dissolved bones.
Moisture	16·24	12·06
[1] Organic matter and water of combination ...	8·97	32·06
Monobasic phosphate of lime	17·42	14·65
equal to tribasic phosphate of lime (bone phosphate) rendered soluble by acid	(27·28)	(22·94)
Insoluble phosphates...	3·08	20·95
Sulphate of lime, alkaline salts, etc.... ...	49·61	18·87
Insoluble siliceous matter	4·68	1·41
	100·00	100·00
[1] Containing nitrogen	—	3·09
equal to ammonia	—	3·75

Recent experiments have proved that it is not absolutely necessary that mineral phosphates should be 'converted' into superphosphates in order to be available as plant-food. If ground to a very fine powder they will also answer the purpose, though less satisfactorily and less rapidly. The most economical and certain way of utilizing mineral phosphates is still to change them into superphosphate before applying to the land. Even when the conditions are such that a non-acid or undissolved manure is to be preferred, other sources of phosphorus are still available in the form of bones,

guano, fish-guano, and basic slag, all of which are better than ordinary mineral phosphate, however finely ground.

It is necessary to distinguish between **dissolved bone** and the mixed manures sold as **dissolved bone-compound.** The latter consist of mineral superphosphate mixed with variable quantities of bone, blood, etc., and usually yield considerably less ammonia than genuine dissolved bone.

Basic slag, basic cinder, or Thomas phosphate powder, is a by-product, containing the phosphorus which is removed in the smelting of iron by the Thomas-Gilchrist process. Ground down to a very fine powder, it makes a cheap and useful phosphatic manure, which has been extensively applied on large tracts of moorland in Germany. Its efficiency largely depends on very fine grinding. From 80 to 90 per cent. of well-ground basic slag should pass through a sieve having 10,000 meshes to the square inch. The phosphoric acid of this artificial form of mineral phosphate exists in a more readily available condition than that of the tribasic phosphate of lime of natural mineral phosphate. Good basic slag contains from 14 to 20 per cent. of phosphoric acid.

Phosphatic manures that have been acted upon by sulphuric acid generally contain some amount of free acid, and are therefore distinguished as **acid phosphatic manures.** The various kinds of superphosphate, including dissolved bones, are examples. The other phosphatic manures, which have not been treated with acid, are called **non-acid phosphatic manures.** Ground coprolites and basic slag are examples. In some cases an acid phosphatic manure, in others a non-acid phosphatic manure, will be the more advantageously applied to the land. As a rule, if the soil is fairly rich in lime, a superphosphate or some similar dissolved manure will be found the most efficacious and economical means of applying phosphorus. On the other hand, for soils deficient in lime, it would probably be better to use bone-meal, raw phosphatic guano, or basic slag. These, therefore, should be applied to soil, a sample of which will not

effervesce when tested with dilute hydrochloric acid. Moorlands, heaths, and many sandy soils are usually known to be deficient in lime, as, on the other hand, chalky and marly soils are known to contain it in sufficiency. It is to the loams of uncertain character that the test should be applied.

Nitrate of soda is an artificial fertilizer of the highest value, for it is readily soluble in water, and the nitrogen it contains is in a form in which it can be immediately appropriated by the plant. Consequently its action is prompt and it is only applied to land on which there is a growing crop ready to make use of it In the absence of a crop, the nitrate is liable to be washed out of the soil, and its value thereby lost. Large natural deposits of nitrate of soda are found on the soil in Peru and Chili, and the salt is purified by dissolving and recrystallizing it. As sold in the trade it contains about 95 per cent., and sometimes more, of pure nitrate of soda, equal to about 15½ per cent. of nitrogen, or 19 per cent. of ammonia. The following is the analysis of an *average* sample of nitrate of soda:—

Moisture	2·59
Chloride of sodium (common salt)	1·22
Other impurities	·36
Pure nitrate of soda	95·83
	100·00

There still lingers a prejudice against the use of nitrate of soda, because it is said to act as a 'whip,' or a 'scourge,' and to 'exhaust the soil.' As a matter of fact, nitrate of soda supplies an indispensable plant-food—nitrogen. But it is only productive of its best effects in promoting the growth of crops when the other essential elements of plant-food are also available in sufficient quantity. Either, therefore, the soil must be in good condition, maintained by the liberal use of dung, or other artificials must be supplied to supplement the action of the nitrate. In the case of corn crops, for example, it is very commonly used in conjunction with superphosphate.

Nitrate of soda is put on the land as a top-dressing to the growing crop. Besides corn crops, it is specially suited to mangel. The proper amount to use is generally about 1 cwt. per acre. When used with superphosphate, the two fertilizers should not be mixed till just before use, or a loss of nitric acid may result. This may be altogether avoided by sowing the superphosphate with the seed, and subsequently top-dressing the young crop with nitrate. Common salt (chloride of sodium) is the chief impurity of nitrate of soda, and is sometimes added as an adulteration.

Sulphate of ammonia, a compound of ammonia and sulphuric acid, is the great rival of nitrate of soda. It is perfectly soluble in water, but less quick in its action than nitrate. At the same time it is richer in nitrogen, of which it contains about 20 per cent., equal to from 24½ to 25¼ per cent. of ammonia. Good samples yield more than 95 per cent. of sulphate of ammonia. It is a refuse product of gas-works, the ammonia, which results from the distillation of coal, being passed into oil of vitriol (sulphuric acid), with which it combines.

Sulphate of ammonia may be used for all purposes to which nitrate of soda is applied. As, however, the salt has to undergo nitrification in the soil, in order that its nitrogen may be converted into nitrate, sulphate of ammonia may be applied to the land somewhat earlier than would be prudent in the case of nitrate of soda, without risk of loss by drainage. In dry weather nitrate acts the more quickly, in wet weather there is not much difference between the two, and in very wet weather there is the risk lest the nitrate may get washed out of the soil before the crop has been able to make full use of it. Which of the two is the more economical manure depends greatly upon the relative market prices, it being necessary to ascertain in which form the unit (1 per cent.) of nitrogen can be purchased the more cheaply.

Calcium cyanamide and calcium nitrate, now largely used, have obtained their nitrogen from the atmosphere by electrical means. The former is prepared by passing nitrogen gas over calcium carbide in the electric furnace.

It contains 19 to 20 per cent. of nitrogen. Calcium nitrate is manufactured by making nitrogen and oxygen combine in the electric arc, and then treating with lime the nitric acid produced. It contains 13 per cent. of nitrogen.

Dried blood, shoddy, hoofs and horns, etc., are organic manures derived from animal refuse. They are all nitrogenous manures, and are nearly insoluble in water. Their nitrogen, therefore, is yielded up but slowly in the soil, where they must undergo decomposition. **Dried blood** is the most rapid of these slowly-acting manures; it contains nitrogen equal to from 12 up to 16 per cent. of ammonia. **Hoofs** and **horns** are the slowest in their action, which may, however, be much accelerated by grinding them to a very fine powder; they yield about 16 to 18 per cent. of ammonia. **Shoddy** or **wool waste** varies in value according to the quantity of wool present, and may contain from 3 to 14 per cent. of nitrogen.

Hoofs and horns are used in market gardens and hop yards, shoddy is chiefly applied to hops, and dried blood is a good fertilizer for fruit trees, besides being also used for cereals.

Soot, much employed as a top-dressing for corn crops, is a nitrogenous manure which owes its fertilizing properties principally to the presence of a variable quantity of salts of ammonia, representing from 2 to 5 per cent. of ammonia. A good sample will contain at least 4 per cent. The amount of ammonia depends largely upon the extent to which the soot is mixed with ashes and other refuse.

Of the foregoing manures, *average* samples will contain the percentages of nitrogen stated:—

	Sulphate of Ammonia.	Dried Blood.	Shoddy.	Soot.
	per cent.	per cent.	per cent.	per cent.
Nitrogen	20·72	10·03	4·75	4·14
equal to ammonia ...	25·16	12·18	5·77	5·03

Other Organic manures, such as rape-cake, mustard-cake, damaged cotton-cake, and similar refuse feeding-cakes, are found to be especially useful on light land deficient in organic matter. They not only give bulk to the soil, but supply it also with nitrogen, the quantity of the latter varying according to the kind of cake. Fresh **sea-weed** contains from ·3 to 1 per cent. of nitrogen, with some potash.

Potash manures are less expensive than was formerly the case, when potash was obtained almost exclusively from the ashes of plants, especially of young twigs of trees. Potash salts are now procured in quantities from Stassfurt and other places in Germany, where they form thick deposits resting upon rock salt. Of these salts the best known is **kainit,** a mineral composed of potassium sulphate, magnesium sulphate, potassium chloride (muriate of potash), and water, usually with magnesium and sodium chlorides. An average sample gave on analysis 12·56 per cent. of potash, equal to 23·25 per cent. of sulphate of potash.

Muriate of potash is the commercial name of chloride of potassium, hydrochloric acid having formerly been called muriatic acid. It is much richer in potash (75 to 90 per cent. pure) than kainit, and, where the saving of carriage is an object, it may be used in preference. **Sulphate of potash** (90 per cent. pure) is also a salt largely used for supplying potash to crops.

Pasture lands are often much benefited by the use of potash salts, and so are clover, potatoes, and root crops.

Potash manures cannot be advantageously applied to so wide a range of soils as are improved by nitrogenous and phosphatic fertilizers. Heavy lands do not, as a rule, respond to potash, because there is usually sufficient of this ingredient available in clays. Light soils, on the other hand, generally yield better crops after treatment with potash salts. As peaty soils are wanting in potash, reclaimed bog lands also pay for applications of this ingredient.

Common salt, as used in agriculture, is the same material as, in a purer form, is known as table-salt.

Chemically, it is chloride of sodium. Its action in the soil is not understood, and is probably as much physical as chemical, for most plants can grow healthily in the absence of either or both of the elements of which it is composed. Salt is usually applied as a top-dressing, in conjunction with nitrate of soda, and it appears to check the tendency which corn crops betray in the direction of rank growth when nitrate is freely used by itself. Cabbage and mangel crops are often much benefited by the application of salt, though in certain districts this is not the case. The useful effect is largely due to the fact that the salt retains moisture in the land for the use of the crop, and so is very beneficial in dry weather. In localities near the sea some quantity of salt is derived from the wind, and may act as a fertilizer. In certain soils the use of salt leads to the formation of a pan (see p. 27), possibly through the attraction of moisture. If present in too large a quantity, salt renders soils sterile.

Gypsum, or sulphate of lime, is the same material as plaster of Paris. Of plant-food it contains lime and sulphur, and hence gypsum is suited to crops like turnips and clover, which require a considerable quantity of sulphur. As, however, superphosphates always contain sulphate of lime, which is one of the products resulting from the treatment of mineral and other phosphates with sulphuric acid, the application of gypsum is unnecessary when superphosphates or dissolved bones are used. As a rule, gypsum can only be usefully applied to soils poor in lime.

There is room for the exercise of considerable skill in the **application of artificial manures,** as regards both time and method. It is very necessary to remember that the object is not so much to manure the land as *to feed the crop.* Of the fertilizers put into the land by the cultivator of the soil, only those portions are effectively utilized which are subsequently recovered in the crop. All that is not so recovered is lost, and the outlay upon it has been incurred in vain. The properties of a fertilizer afford a safe guide to the time and method of its application. Thus, soluble and rapidly-acting manures are preferably applied in the spring, when there

is the prospect of a vigorously growing crop ready to make use of them. The most striking example is afforded by nitrate of soda, which should never be applied till the crop is, as it were, naturally waiting for it; if not promptly taken up by the plant, it can hardly escape being washed out by rain. The same remarks apply in only a less degree to ammoniacal manures, for, though fertile soils have a great retentive power for ammonia, yet the latter is so soon converted into nitrates that it is liable in this form to be lost. Slowly-acting manures, like bones, fish guano, and shoddy, may be safely applied in the autumn, as the process of nitrification requires in their case a considerable time.

As phosphatic and potash manures are held by the soil, so that there is very little risk of their being washed out, the time of their application may be determined according to convenience. Phosphates, for example, are very commonly sown with the seed, the one operation serving both for the seed and for the finely-divided fertilizer.

As far as practicable, manures should be reduced to the condition of a fine powder before application, not only to ensure their more rapid action but also to secure a more uniform distribution. With the same object artificial manures are often mixed with gypsum, ashes, sand, or fine dry soil, especially if intended to be broadcasted by hand.

On light open soils, of little retentive power, manures that are only slightly soluble should be used, otherwise they are liable to be speedily washed out.

MANURES FOR SPECIAL CROPS

As **wheat** occupies the land about twice as long as oats or barley, it is usually able to obtain a sufficiency of phosphates in the dung employed to manure the crop and in the residues of phosphates which exist in the soil. But on light soils, especially if only a moderate dressing of dung has been given, some phosphatic manure may be added at the time of sowing in autumn.

Three cwt. of superphosphate per acre on land rich in lime, or 2 cwt. of phosphatic Peruvian guano, or 3 cwt. of fine bone-meal, on land poor in lime, should suffice. In spring, wheat is top-dressed with nitrate of soda, at the rate of 1 to 1½ cwt. per acre, but several moderate applications are better than one large dressing.

Barley and **oats** should, at the time of sowing, receive the same dressings of phosphatic manures as recommended for wheat. They may also be top-dressed with nitrate of soda, though this fertilizer must be cautiously and sparingly used in the case of barley if the production of malting grain is the object in view. Barley following wheat may be more profitably manured than barley following turnips which have been fed off by sheep receiving **cake.**

In Scotland, and in the northern counties of England, **root-crops** are manured more heavily than in the south. In the north, with a colder climate and a later and shorter season, from 10 to 15 cwt. per acre of artificial manures are profitably used for turnips, whereas in the south not more than 3 or 4 cwt. can be usefully employed.

Turnips and **swedes** usually receive a full dressing of dung, notwithstanding which, artificial phosphates should also be used. They are specially valuable in helping the young turnip plant through the most critical period of its life, and thus in carrying it beyond the risk of destruction by the ' fly ' or other insect enemies. Moreover, these cruciferous roots are more responsive than any other crop to phosphatic manuring. On land containing a sufficient supply of lime, 3 to 5 cwt. per acre of superphosphate may be drilled in with the seed, whilst on soils poor in lime 5 or 6 cwt. of basic slag may be similarly applied. Nitrate of soda will not be required unless only a very moderate dressing of dung has been given, in which case 1 cwt. of nitrate per acre may be thrown between the rows after hoeing out, or 'singling.'

It is the practice in Norfolk to grow the greater part of the swedes and almost all the turnips with artificial manures only, no dung being applied.

The mangel crop responds less freely to phosphatic manuring than is the case with turnips. Therefore, where a heavy dressing of dung has been given, the addition of phosphates is not recommended for good soils. If, on the other hand, only 10 to 12 tons of dung have been used per acre, then 3 cwt. of superphosphate on land rich in lime may be given per acre, and 5 or 6 cwt. of basic slag, or 3 or 4 cwt. of phosphatic Peruvian guano, or of fine bone-meal, on land poor in lime.

It is generally considered in Norfolk that phosphates have very little beneficial action upon mangel, when dung is used. For this crop nitrate of soda is preferable.

Beyond the nitrogen they receive in dung it is not economical to apply nitrogenous manures to **leguminous crops.** On the other hand, phosphatic and potassic fertilizers may be profitably used, and, in some classes of soil, gypsum also, as these crops are capable of taking up comparatively large quantities of lime.

Rotation grasses, or 'seeds,' usually pay for nitrogenous manuring, notwithstanding the presence of clover in the crop. As a large and immediate yield of fodder is looked for, rather than the production of fine herbage and a close greensward, liberal dressing may be resorted to. Nitrate of soda, at the rate of 2 cwt. per acre, and sometimes to the extent of 3 cwt., or more, may be put on in dressings of 1 cwt. per acre at a time. On soils containing a sufficiency of lime, 2 or 3 cwt. of superphosphate or of dissolved bones may be used. Where lime is scarce, 3 cwt. of bone-meal or of phosphatic Peruvian guano, or 5 cwt. of basic slag, will be found effective. On light soils, deficient in potash, 2 or 3 cwt. of kainit per acre, or 1 cwt. of sulphate of potash per acre, may be used.

In the manuring of **permanent grass land** the proportion which it is desired to maintain of leguminous to gramineous herbage must be kept in view. The best manure of all is farmyard manure, though for an occasional crop of hay artificial manures may be used; they should, however, be resorted to with caution. Too free an employment of nitrate of soda, for example, would unduly favour the grasses at the expense of the clovers.

About 1 cwt. per acre of nitrate of soda, or of sulphate of ammonia, constitutes a moderate dressing. The phosphatic manures mentioned for rotation grasses, with kainit for light lands, will be found suitable for permanent pasture. Basic slag, bones, guano, and other undissolved manures, are best applied to pastures in the autumn.

The most profitable way, however, of improving **grass land** is to manure it by feeding stock upon it with cake. If cattle or sheep are fed on the land with plenty of cake, there will be no need for the direct application of nitrogenous manures. The only artificials then required will be phosphates, and perhaps potash.

For **hops** and **fruit,** shoddy, rape-dust, and bulky nitrogenous manures, such as fish manure, hoofs and horns, etc., are dug in during the autumn. Phosphatic manures are also used as for grass lands, the dressing being increased when dung is scarce.

Plants of the **cabbage tribe,** including kale and kohl rabi, are gross and greedy feeders, so that bulky organic manures may be supplemented by guano. Three or 4 cwt. per acre of nitrate of soda may be used, and, in some cases, salt. Where potash is deficient, kainit should be used. In dry weather a top-dressing of 3 cwt. of salt to the acre will be found very useful, as it attracts moisture to the plant.

PART II.—THE PLANT.

CHAPTER IX.

SEEDS AND THEIR GERMINATION

Most farm and garden crops are raised from seed, though some, such as potatoes, are not. It is difficult to see what changes are taking place when the seed is in the ground, but it is easy to make seeds grow under conditions permitting continuous observation.

One method is to take a clean piece of red roofing tile and place it in a shallow dish. The seeds are laid upon the tile, and water is gently poured into the dish to rather more than half the thickness of the tile. The dish, covered with a board or slate, is put on a shelf in a warm cupboard, and the seeds examined daily. The tile being unglazed the water soon rises to the upper surface, and moistens the seeds. During the first day or two these will swell, as may be proved by comparing them with dry seeds. Then the skin or coat will be seen to have burst, and a small whitish structure to protrude. The seeds have *sprouted* or *germinated*. Broad beans may be conveniently selected for observation.

First, **examine the dry seed.** Notice the hard smooth coat, and, at one end, a blackish mark (the *hilum*) where the seed was attached to the pod. Carefully slit open the coat with a penknife, and peel it off. That which is left consists of two similar halves, which are laid apart by pushing the knife blade between them. These are the **seed-leaves,** or **cotyledons.**

Further examination will show that the seed-leaves are attached, not to each other, but to a short spindle-shaped structure lying at the margin of the seed, and almost hidden till the seed-leaves are forced apart This structure is called the *axis*.

Next, take a bean that has lain on the moist tile for a day or two. The penknife now strips off an outer leathery coat, beneath which is a much thinner transparent one. The outer coat is the **testa,** the inner one is the **endopleura.** These can easily be made out in a nearly ripe bean or a cooked broad bean. They are also brought into view in peeling a walnut.

Each day the bean which appears to be most advanced should be taken off the tile and examined, cutting it if need be for this purpose. In the course of a week or so it will be seen that the axis has grown considerably. That end of it (the **plumule,** from Lat. *plumula*, a little feather) which was turned in between the flat faces of the seed-leaves will begin to develop small leaves. It is, in fact, the primary **shoot**—*i.e.*, the main stem with its leaves. The other end (the **radicle,** from Lat. *radix*, a root), which was more towards the outer margin of the seed, will also have lengthened, and fine threads or fibres will have grown out from its sides. It is the primary or main **root.** Fig. 46 shows the parts of a pea seed, twice the natural size.

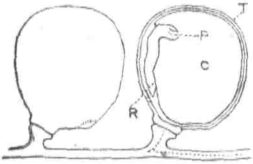


FIG. 46.—SEED OF PEA DISSECTED.
C, cotyledon.
R, radicle, or young root.
P, plumule, or young shoot
T, testa, underlaid by the endopleura.

Several germinated beans may be planted in the ground, or in a flower-pot, and still kept under daily observation. Before long the curved plumule will peep above the soil, shoot up rapidly, gradually straighten itself, and expand its leaves.

By pulling up the young plant, or **seedling,** it will be found that the radicle has developed into the primary root, bearing fibrous **secondary** or **lateral** roots.

The seed, then, consists of a dormant plantlet (consisting of plumule, radicle, and cotyledons) covered by protective coats.

What makes the bean seed germinate? A sack of beans may be kept in a barn, or a bin of beans in a

shop, for an indefinite time, and they will not begin to grow. If, however, by some chance they got wet, sprouting or germination would begin. This shows that **moisture** is necessary in order that germination may take place. To prove this, some beans may be placed on a tile that is dry, and is kept dry, while other beans are put on a moist tile. The beans on the dry tile will undergo no change.

But the presence of water is not the only condition. It will be remembered that the tile in its dish was put in a warm cupboard. If, in the winter time, another lot of beans had been placed on a tile, and the dish with its water had been left out of doors, where it was nearly cold enough to freeze the water, germination would have been much slower, and it might not have begun at all. Hence it is learnt that a certain degree of **warmth**—a certain temperature—is necessary in order that germination may take place. It has been proved that seeds do not usually germinate below a temperature of 37° F. (the freezing point is 32° F.). But the temperature is different for different seeds. Thus, wheat and barley will not germinate below 41°, nor will peas below 44°, maize below 49°, nor pumpkin seed below 56°. Hence, if wheat were sown at the end of November, as it sometimes is, and if the winter were so cold that for weeks the thermometer did not rise above 40°, the wheat would not germinate, though sufficient moisture might be present.

In the same way, as there is for each kind of seed a certain *minimum* temperature *below* which it will not germinate, so there is a *maximum* temperature *above* which it refuses to do so. This higher limit of temperature is 140° for barley, 102° for peas, 108° for wheat, and 115° for maize and pumpkin seeds.

Between these extreme temperatures there is, in each case, *a temperature most favourable to germination*, but this **optimum** temperature is not necessarily midway between the two. For wheat, barley, and peas, it is about 89°, for maize and pumpkin seeds it is 93°.

The plants named have only been selected as

examples, and the figures are collected in the following table:—

TABLE XX.—TEMPERATURE *of* GERMINATION (*in degrees Fahr.*).

Seeds.	Minimum.	Optimum.	Maximum.
Wheat	41	89	108
Barley	41	89	104
Maize	49	93	115
Peas	44	89	102
Pumpkins	56	93	115

For seeds in general, the minimum temperature ranges from 40° to 55°, and the maximum from 100° to 116°. The optimum temperature lies between 79° and 94°.

Another condition of germination is the **presence of air**, though this can only be actually proved by means of chemical apparatus. Still, if a small wide-mouthed bottle is filled with broad beans, a little water poured in, and the mouth tightly stopped, the beans will be *seen to begin germinating. After a while, however,* they will wither. The reason is that the small bottle could not hold much air, and, of that which was there, the **oxygen** has been used up by the germinating seed, and the supply exhausted. The process of germination involves oxidation, and ceases when oxygen gas, which makes up one-fifth of the atmosphere, is no longer available. In the small bottle the oxygen gas has disappeared, and carbonic acid gas has taken its place.

Root and shoot.—Various other facts may be learnt from the germinating beans. Take several sprouted beans and plant them one by one *upside down* in the ground—that is, with the radicle towards the surface of the earth and the plumule pointing downwards. At the same time, for comparison, plant a few more germinated beans *upright* in the ground.

Let the seedlings grow till they have formed green shoots above the ground, then pull them up for examination. In the case of the inverted seeds, the plumule,

or *ascending axis*, or *shoot*, will have curved completely round in order to find its way into the light. At the same time the radicle, or *descending axis*, or *root*, will have curved over the top of the seed and commenced to grow downwards into the soil and away from the light. Compare one of these curved seedlings with a straight one from a bean that was planted upright.

This property of the shoot to grow towards the light, and of the root to grow into the soil is a most important one. Were it otherwise, and if all seeds required to be planted upright, the labour of sowing small seeds like those of clover, and turnips, and onions would be enormous.

Plant food.—Let some of the germinated beans remain on the moist tile; do not plant them at all. After a time they will begin to wither, and eventually they will die. Smaller seeds, like turnips and clovers, will die much more quickly. Probably, at the same time, they will become covered with a delicate mould, due to the growth of a fungus.

Why does the seedling left upon the tile die, whilst the one planted out lives? On the tile the plant has at its disposal nothing but air and moisture. The other plant not only has these, but it is brought into touch with the soil. That it comes into very close contact with the latter is shown by pulling up a growing seedling, and observing the extent to which the particles of soil cling to the delicate **root-hairs** that clothe the roots. It is reasonable to conclude that the planted seedling is able to obtain from the soil something which the seedling on the tile could not get. This, indeed, is the case. The soil contains *plant food*—*i.e.*, a very dilute solution of certain mineral substances (*see* p. 19)—and it is owing to the lack of this food that the unplanted seedling perishes.

At this stage another question suggests itself. The unplanted seedling dies because it cannot obtain from air and water such food as will enable it to live and grow. But the seed, when first placed on the tile, was supplied with nothing but air and water at a suitable degree of warmth, and yet it began to grow. Whence

came the food, other than that in air and water, which permitted of this earliest growth?

The answer is that the material, other than that in air and water, required for the purpose of germination, is supplied by the seed itself. The thick, fleshy seed-leaves, so well seen in beans and peas, are not only the first leaves of the young plant, but they contain a store of nutriment which is used up in enabling it to commence its independent or individual growth. It had already undergone some growth while it was connected with the plant which produced it, that is, with its parent.

In view of its subsequent independent growth, the parent plant supplies its offspring—the seed—with nutriment that shall enable it to make a start in life on its own account, by carrying it through the earlier stages of its existence, till it is sufficiently supplied with organs, in the form of leaves and rootlets, which will enable it to obtain food for itself.

Seeds like the bean.—Many well-known seeds are constructed on the same plan as the bean. They consist of an axis, bearing a pair of fleshy leaves stored with food, the whole wrapped up or enclosed in a couple of close-lying coats. Such a seed is merely a young plant in an envelope. Of this nature are the seeds of all leguminous or pulse crops, such as beans, peas, clover, sainfoin, lucerne, vetches, furze, etc. So are the seeds of all cruciferous crops, such as turnips, cabbages, radishes, mustard, and cress.

There is another large group of seeds which differ in structure from seeds of the bean type, though there is no essential difference in their mode of growth. As a convenient example of this group a grain of wheat* may be taken.

Germination of wheat.—Let some grains of wheat be germinated and otherwise examined in the same way as the bean seeds. The grain will swell, and in due

* As will be explained in the sequel, grains of wheat and other cereals are really *fruits*, *i.e.*, seeds with something else in addition.

course, from one end of it, rootlets will be seen to protrude, whilst close by will arise the plumule or shoot. Dissected with a penknife, however, the wheat grain (fig. 47) is at once seen to differ from the bean. At the base of the grain, on the side away from the groove or furrow, a *small oval patch* is noticed. This may easily be detached, especially from a grain that has been soaked in water for a day. Remove this little patch from several grains and put these on the germinating tile with some other grains. The latter will germinate. The former never will. Hence, in the removal of the tiny structure at the base of the grain, the living part of the grain has been taken away.

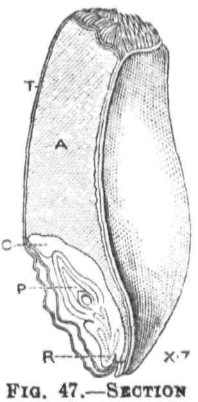


FIG. 47.—SECTION OF GRAIN OF WHEAT.

T, flowering glume and pale, closely enveloping the pericarp.
A, endosperm.
C, scutellum
P, plumule, and
R, radicle of embryo.

Think now of the bean seed: what is its living part? It is the axis with its seed-leaves—the young plant; and it is this which grows into the robust bean plant. Similarly, it is the tiny structure which can be lifted away from the grain on the point of a penknife that grows into the slender wheat plant. This minute structure, then, corresponds with all that is contained inside the protective envelope of the bean. It is the **germ** or **embryo plant** (fig. 47, P, R), the plantlet, consisting, as in the bean, of an axis (plumule and radicle), which in this case is attached to a *single* seed-leaf, or cotyledon. The central part of the latter (*scutellum*) is applied to the endosperm, while its sides are folded back so as to wrap round the axis. When the wheat grain is crushed the germ falls out, and millers call it the 'chit.' It is made up of a great number of very small thin-walled cells, and, on account of its oily nature, it is less friable, and therefore less easily powdered, than the rest of the grain.

It is now apparent that whilst the bean seed contains nothing but the embryo of the future plant, the wheat grain contains the embryo and something in addition. This additional matter, scraped out with a knife, is seen to be made up chiefly of the whitish powder known as flour (fig. 48, D). As the growth of the germinating grain progresses, the grain gradually loses this material, which is called upon to supply the first food for the germinating seed.

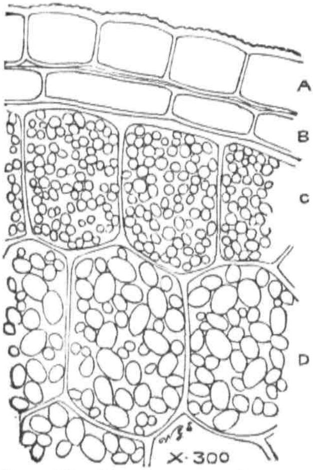


FIG. 48.—SECTION OF OUTERMOST PART OF WHEAT GRAIN (magnified 300 times).
A, epidermis, with an underlying series of cells almost obliterated by pressure.
B, cells with thick walls.
A and B are more or less coloured, B giving the brown colour of bran.
C, thick-walled gluten cells filled with fine-grained protoplasm and containing granules of albuminoid nature.
D, thin-walled cells, filled with starch granules (flour), forming the mass of the grain.

What, then, is really the *difference* between such types of seed as are illustrated by the bean and the wheat grain? Obviously this, that in the wheat grain there is a **minute embryo** resting against a much larger mass of food material **(endosperm)**, this lying outside it; while the bean seed contains nothing but a **large embryo**, the size of which is due to the food material stored within its fleshy seed-leaves.

The term *albuminous* is applied to seeds which contain, besides the embryo, a store of food (*endosperm*) lying outside it; while those seeds which, like the bean, contain nothing but an embryo, are called *exalbuminous*. The difference is merely *one of position*. **In the exalbuminous seed the nutriment is entirely stored in the embryo; in the albuminous seed it is not.**

Albuminous seeds vary considerably in respect of the relative size of embryo and endosperm. Sometimes the embryo is very minute, as in the iris and the poppy. In such a seed as the bindweed, on the other hand, the embryo is relatively large. The position of the embryo in the albuminous seed likewise varies. In wheat it lies at one side of the base, in the sedge it is central, in the chickweed it is coiled round the store of nutriment, in seeds of the onion and of the potato it is coiled up in the mass of nutriment.

Besides the seeds that have just been named, the following are also mentioned as affording easily obtained examples of albuminous seeds: Buttercup, violet, spurrey, celery, parsnip, carrot, plantain, buckwheat

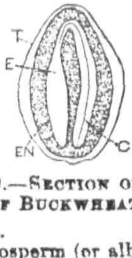


FIG. 49.—SECTION OF SEED OF BUCKWHEAT.

T, testa.
EN, endosperm (or albumen).
E, embryo, consisting of an axis and two cotyledons.
C, the cotyledons folded back.

FIG. 50.—SECTION OF SEED OF BEET.

T, testa.
E, endosperm.
EM, embryo, with its two cotyledons.

(fig. 49), dock, sorrel, mangel, beet (fig. 50), sedges, and all cereals and grasses. The seeds of the castor oil plant, procurable at any chemist's shop, are particularly useful for examination on account of their large size.

Of **exalbuminous seeds,** besides those of leguminous and cruciferous plants, noticed on page 132, may be mentioned such familiar seeds as those of the maple, sycamore, horse-chestnut, apple, cherry, vegetable marrow, cucumber, pumpkin, sunflower, yarrow, together with the walnut, hazel-nut, beech-nut, and acorn.

The green colour of plants.—Return now to the young bean plants and learn from them one more lesson. The sprouting bean upon the tile is *white*. When it is planted out, the shoot that at length peeps through the soil is also *white*. As it straightens itself it turns **green**, and keeps this colour till after flowering. If a watch be kept upon the ground in which seeds are sown, whether in the field or in the garden, it will be observed that the young shoots as they work their way out of the soil are white, or nearly so, but that they speedily turn green. Moreover, if a vigorous seedling be pulled up, it will be seen that whilst the part above ground is green, the part below ground is white.

In the soil it is always dark; above the soil it is not. This suggests that light may have an effect in producing the green colour, and it is easily proved that it does. If a bean seedling is planted in a flower-pot and put in a dark cupboard, although it continues growing for some time it does not turn green, but it may be caused to do so by bringing it into the light. When a branch of a geranium or fuchsia is diverted into a dark box for a time it loses its green colour. If a slab of wood or stone has been laid flat upon garden turf for a week or two, the grass will be found quite blanched when the slab is lifted, and will only slowly reacquire the green colour. The green colouring matter or pigment, the presence of which is usually most noticeable in the foliage leaves of a plant, is called **chlorophyll.** It is easily extracted from dried parsley leaves by means of alcohol.

Malting.—The process by which barley is changed into malt is one of germination. The barley grain is placed under suitable conditions of moisture and warmth, with free access of air. It soon begins to sprout, and at the same time a chemical change is set up inside the grain, resulting chiefly in the *conversion of starch into malt-sugar*. Most of the floury material contained in the grain is starch, an insoluble compound of carbon, hydrogen, and oxygen. But plants are usually incapable of consuming solid food; their nutri-

ment must be in the fluid form. During germination the starch, which is insoluble, becomes changed into malt-sugar, another compound of carbon, hydrogen, and oxygen, but soluble in water. On account of its solubility the sugar can be carried in solution to the young growing plant, and there made use of as food. But the object of the maltster is attained when a portion of the starch is converted into sugar, and at this stage he kills the young plant by suddenly raising the temperature above the limit of 104° (*see* p. 130). In the place of living barley-grains filled with insoluble starch there are now dead malt-grains containing soluble malt-sugar. The malt is steeped in water, which, by dissolving the sugar, is converted into the sweet wort from which beer is made. What are known as malt-combs consist of the radicles of the young plants, which are removed by screening.

FIG. 51.—DISINTEGRATION OF A GRAIN OF WHEAT STARCH BY DIASTASE (highly magnified).

A, B, C, D, E, represent successive stages.

The conversion of the starch into sugar (fig. 51) is brought about by the activity of a substance termed *diastase*, a member of a very important group of bodies, known as *ferments* or *enzymes*, which are protein compounds (*see* below).

Starch is a good example of the group of substances which chemists term **carbohydrates**, that is, compounds containing carbon, hydrogen, and oxygen, the two latter being present in the same relative proportions in which they combine together to form water—namely, two volumes of hydrogen to one of oxygen. But although starch makes up a large proportion of the reserve materials of most seeds, whether albuminous or exalbuminous, other kinds of carbohydrates are present.

Many seeds also contain **fats** or **oils**—linseed, rape-seed, poppy-seed, coco-nut, and Brazil nut are examples.

Fats, like carbohydrates, consist of carbon, hydrogen, and oxygen, but the oxygen is present in a relatively smaller proportion than that in which it occurs in carbohydrates.

All seeds include, amongst their reserve material, certain compounds called **proteins** (or proteids), which are distinguished from carbohydrates and fats by containing nitrogen and sulphur, together—in some cases—with phosphorus.

Seeds, then, are **storehouses** of rich concentrated food, consisting of proteins, carbohydrates, and often of fats also. Many of them are specially cultivated as affording nutritious food for men and animals. It is for this reason that the cereal grains, such as wheat, barley, oats, maize, rice, etc., and the pulses, such as beans, peas, lentils, etc., are so largely grown. In the ordinary course of nature, the stored-up food in these seeds would be utilized in starting the young plant on its independent existence, but man steps in and diverts this food to his own purposes.

The changes which take place in the seed during germination, and result in converting its stores of nutriment into soluble plant-food, are very complicated, and not yet thoroughly understood. It has been proved, however, that diastase is only one of a number of **ferments,** the activity of which effects the transformation of insoluble seed-stuff into dissolved plant-food. Ferments that convert starch into sugar are known as *amylolytic* (*i.e.*, starch-dissolving), while those turning proteins into a soluble form are termed *proteolytic* (*i.e.*, protein-dissolving).

Anybody who has witnessed a wet harvest will have had an opportunity of seeing wheat or barley grain sprout in the ear. Warm, wet weather causes the grain to germinate before it can be carried off the field. This suggests a highly interesting question.

Before flowers are formed on the parent plant, no trace of seeds can be found. The seed is produced by the flower, and obviously *grows* till it has attained maturity; that is, till the seed is 'ripe.' Why does not the seed, under ordinary circumstances, continue to

grow? Why does it stop growing when ripe? Why is there what may be called a *resting stage?* These are puzzling questions, and it is not safe to say more than that the resting period depends on *the condition of the ferments.* Diastase and other ferments are present in the germinating seed, but in very minute quantities. It is characteristic of them that extremely small quantities are capable of effecting extensive chemical change, and that they are neither changed nor destroyed by their own activity. Exposure of the seed to conditions of moisture and warmth, which are recognized by experience as 'favourable to germination,' have the effect of exciting the ferments into activity, the result of which is that the stores of insoluble material are rendered available as plant-food, and are transported in solution to the seats of growth.

A fresh seed is a living thing—it is alive just as much as a hedgehog which lies motionless throughout its long winter sleep at the bottom of a hedgerow. Inside the seed is the living plant in its resting stage—the *embryo.* In contact with the embryo, or within its substance, is the material which will constitute its first food when it resumes growth.

CHAPTER X.

STRUCTURE AND FUNCTIONS OF PLANTS—ROOTS, STEMS, AND LEAVES

Shoot and Root.—When studying the seed we found that the plantlet this contains consists of plumule and radicle, which grow upwards and downwards respectively during germination (p. 130), becoming the *ascending axis* and *descending axis* of the mature plant. The convenient term **shoot** is used to designate a stem with its leaves, and we may therefore speak of the plumule as the *primary shoot,* while the radicle is the

primary root. From the sides of these axes *secondary* shoots and roots arise, which in their turn may give off branches, and so forth. The final result, as a rule, is a complicated plant-body, which stretches its branches in all directions into the soil, on the one hand, and into the air, on the other.

Meaning of the Branching Form of Green Plants.—If we compare an average green plant with an average animal we shall see at once that the former is fixed and more or less branched, while the latter moves about and is compactly shaped. The primary reason for these differences is to be found in *the nature of the food*, and before proceeding to consider in detail the different kinds of root, stem, and leaf, as regards their shape and structure, we shall find it instructive to make a few simple physiological enquiries.

Living Substance, or Protoplasm.—The *essential* part of every organism, whether plant or animal, consists of an exceedingly complex substance called protoplasm, often known as 'the physical basis of life.' In higher plants it is commonly obscured, so to speak, by the products of its activity, such as cellulose, wood, and cork, but by means of the microscope its presence can easily be demonstrated. If, for example, an uninjured stinging-hair from the leaf of a nettle be so examined, the interior of its swollen base will be found to present an interesting and remarkable spectacle. Lining the firm external membrane there is a clear layer of semi-fluid substance surrounding a central space filled with sap. This layer is drawn out into branching threads or strands, which traverse the central space. If one such strand be closely examined under a high power of the microscope it will be found to contain innumerable granules, which by their constant movement enable us to discover that the substance of the strand is flowing this way or that. The semifluid contents of the base of the hair, which are in a state of such restless activity, afford a good example of living substance, or protoplasm.

Metabolism.—Protoplasm differs from non-living substance in being the seat of a constant series of chemical

changes, to which the term metabolism (Greek, *metabolé* change) is technically applied. The reason is to be sought in the fact that living matter constantly displays various forms of activity—*e.g.*, movement—as seen in the nettle-hair, and, still more obviously, in animals. Such activities would be impossible without a supply of **actual** or **kinetic energy**, as may be illustrated by the case of a mill-wheel, which is made to turn round by the actual or kinetic energy of moving water. Such energy is obtainable in various ways. In the mill-stream, for example, it is set free when the sluices of the mill-dam are opened, and the water allowed to escape. The head of water in the mill-pond represents so much **stored** or **potential energy**, which becomes kinetic energy when the sluices are opened. Similarly a highly complex unstable chemical substance may be regarded as a store of energy, which is liberated when the substance breaks down into simpler compounds. High explosives, such as cordite, afford an excellent illustration. The kinetic energy by which projectiles are driven is derived from their sudden decomposition or explosion. In the living plant or animal the requisite kinetic energy results from the breaking down of complex unstable protoplasm into simpler and simpler substances, the ultimate chemical result being water, carbon dioxide (CO_2), and simple nitrogenous substances, which, being too stable to decompose further, and therefore useless to the organism, are known as **waste products.** That part of metabolism which is concerned with down-breaking processes is known as **destructive metabolism,** or more briefly as **katabolism.**

It is clear that if the process of waste just described were not in some way compensated, the living organism would rapidly become smaller and smaller, and ultimately perish. Katabolism, however, is always associated with and balanced by **constructive metabolism,** or **anabolism,** including those metabolic changes by which simple substances are built up into more and more complex ones, the ultimate result being protoplasm. At the same time there is a conversion of kinetic energy into potential. The entire cycle of chemical

changes in the organism is conveniently represented by means of a diagram known as the **metabolic staircase** (fig. 52).

Food and Feeding.—From what has just been said, it is clear that, if wasting of the body is to be counterbalanced, materials for the upbuilding or constructive processes must be taken in from the exterior. These materials constitute the **food.** In the case of a green plant they consist of carbon dioxide (CO_2), water, and simple mineral substances in solution. It is important to notice that such food is entirely of gaseous or liquid nature, and is *absorbed by the general surface of the body.* There is no internal digestive cavity. We can now see *why* an ordinary plant is of branching form. This is a means of *increasing the surface* by which food can be

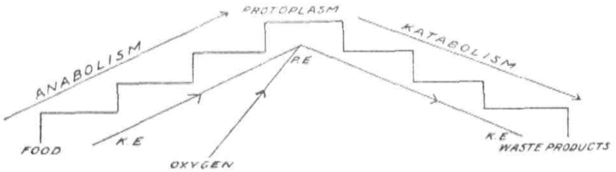


FIG. 52.—METABOLIC STAIRCASE.
K E, kinetic energy. P E, potential energy.

absorbed. The leaves collectively present a large area for taking in carbon dioxide from the air, while the root-system comes into contact with a considerable amount of soil, and is able to absorb a large quantity of water with dissolved mineral substances. It must not be forgotten that food provides the material for *growth,* as well as for the repair of waste.

Animals, as will appear in the sequel, require more complex food than green plants. It is partly *solid* in form, hence the necessity for an internal digestive cavity. Not being everywhere present, the animal has to seek it, hence a compact shape and powers of locomotion.

Leaf-green or Chlorophyll.—The two sides of the **metabolic staircase for green plants** (fig. 52) **are of**

equal length, and we can broadly say that as much kinetic energy is converted into potential during its constructive processes as potential into kinetic during the down-breaking or destructive processes. In cases where growth is taking place the former kind of conversion must obviously predominate, for the formation of *new* protoplasm means increased storage of energy.

At first sight, therefore, there would appear to be no available surplus of kinetic energy produced for carrying out the various bodily activities, while in growing organs, as just mentioned, more kinetic energy is transformed into potential during anabolism than is liberated during katabolism. Compensation of waste, to say nothing of growth, would indeed be impossible if the green plant were not able to draw upon an outside source of kinetic energy. Such a source, however, is afforded by the kinetic energy of the sun's rays, which are utilized in the first constructive stage, where water and carbon dioxide enter into a chemical reaction by which non-nitrogenous organic matter is produced, while at the same time free oxygen is liberated. This may be roughly represented thus:—

$$H_2O + CO_2 = CH_2O + O_2.$$

The green colouring matter, or **chlorophyll**, of leaves and young stems enables the protoplasm of these parts to use the kinetic energy of sunlight for the purpose indicated. The exact way in which chlorophyll is able to do this is still a matter for conjecture, and affords one of the most difficult problems in plant physiology.

A very small amount of observation will show that leaves are of many different shapes, and are arranged in a large number of ways. Shape and arrangement alike have reference to advantageous display with regard to air and sunlight.

Breathing or Respiration.—The breaking down of the complex substance of the living body, by which kinetic energy is rendered available, is essentially a process of slow combustion or **oxidation**. In order that it may go on with sufficient rapidity it is necessary that free

oxygen should be introduced into the system. Breathing or respiration is concerned with (1) this intaking of free oxygen, (2) the removal from the body of the waste product carbon dioxide.

It is very important to clearly understand that plants and animals breathe *in exactly the same way*, and nothing could be more erroneous than the second part of a statement sometimes met with to the effect that 'animals breathe in oxygen and breathe out carbon dioxide, while *plants breathe in carbon dioxide and breathe out oxygen.*' This mistaken idea has arisen from the fact that green plants, in the presence of sunlight, *give out oxygen as a by-product* during the first step in the constructive processes (p. 143). The amount is so large that it entirely swamps, so to speak, the carbon dioxide *simultaneously given out as a result of breathing.* During the night, however, the latter process becomes obvious, and this is why green plants are undesirable in a bedroom.

We are now in a position to successively consider roots, stems, and leaves. In all cases we shall find a close relation between form and use or function.

ROOTS

Characters of Roots.—Young roots are pale in colour, while old ones are brown, owing to the presence of a protective coating of cork. Chlorophyll is never present, and would indeed be useless, for roots grow away from the light and into the ground, where their work is done. Another negative character of roots is found in the absence of leaves. In ordinary language the name 'root' is given to any part of a plant growing underground. We shall see, however, in the sequel that many apparent roots are really underground stems (p. 151).

The root is further characterized by certain peculiarities of structure. It possesses a firm central axis, or vascular cylinder, containing elongated tubular elements of two kinds—(1) some with firm, woody walls, constituting the wood, and (2) others with soft walls,

making up the **bast.** Wood and bast, in the vascular cylinder of the *young* root, have a radial arrangement, *i.e.*, when looked at in a cross section (fig. 53) they are situated on different radii. We also find that the delicate tip or **growing point** of a root is covered by a thimble-shaped **root - cap,** which serves as a protection while it is pushing its way through the soil. The growing point of a stem has no such cap, and its tender young cells are protected merely by their position in the heart of a bud. Branch - roots arise deep within the tissues of the parent root, gradually forcing their way to the exterior. This again must be regarded as a protective arrangement.

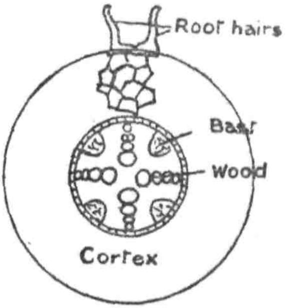


FIG. 53.—CROSS-SECTION OF YOUNG ROOT (magnified).

Kinds of Root.—There are two chief kinds of root. One is the **primary** or **tap-root,** well seen in the radish, carrot (fig. 54), parsnip, shepherd's purse, etc. It is the developed radicle of the seed (fig. 56). The other is the **fibrous root,** of which the onion, lily (fig. 60), wheat (fig. 55), barley, and all grasses afford good examples. Many of the fibres of such roots are **adventitious,** *i.e.* they grow from the stem. All kinds of roots are modifications of one of these types. But even tap-roots are furnished with a large number of lateral roots or root-fibres, and these again with root-hairs, as may be seen by pulling a young bean plant—and many other plants—out of the ground.

Functions of Roots.—Roots have a *mechanical* function, or duty—that of fixing the plant in the ground. They compete with one another for the plant food contained in the soil, and the intensity of this competition may be realized by looking at the under side of a piece of turf, when innumerable root fibres will be seen matted together. Tap-roots are able to use the food which is contained in the deeper layers

of the soil, and this is one reason why weeds like plantains and dandelions are so well able to compete with grasses, or to flourish in hard, dry ground exposed to the sun. Fibrous rooted plants, such as many grasses, are dependent on the food contained in the surface layers of the soil.

FIG. 54.—ROOT OF A CARROT SEEDLING, the stout tap-root being the direct result of the growth of the radicle.

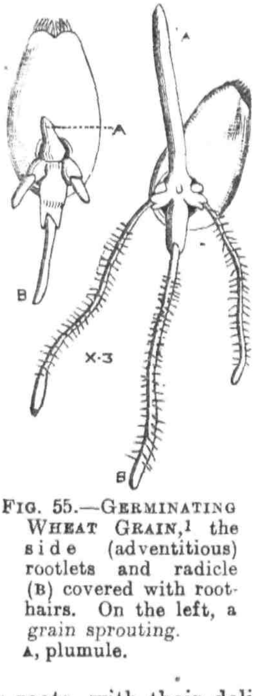


FIG. 55.—GERMINATING WHEAT GRAIN,[1] the side (adventitious) rootlets and radicle (B) covered with root-hairs. On the left, a grain sprouting. A, plumule.

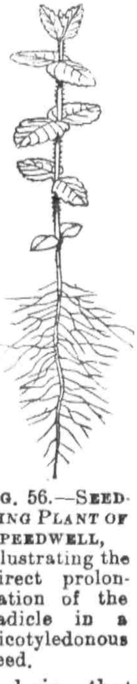


FIG. 56.—SEEDLING PLANT OF SPEEDWELL, illustrating the direct prolongation of the radicle in a dicotyledonous seed.

It is the young roots, with their delicate hairs, that are chiefly engaged in obtaining plant-food from the soil. These are made up of cells, through the walls of which solid matter cannot pass. Consequently all the food that enters the plant from the soil must do so in

[1] The '× 3' on the illustration indicates that it is drawn three times the natural size.

solution by means of diffusion of liquid, technically known as **osmosis.** If a piece of bladder or parchment paper, free from holes, is made into a sort of bag, filled with a solution of sugar, tied up, and placed in a vessel of water, this kind of diffusion can be readily observed. After a time the bag will swell up and become tense or turgid, showing that water has diffused *into* the bag (endosmosis). But, to a lesser extent, sugar solution has diffused *out of* the bag (exosmosis), for the water in the vessel has acquired a sweetish taste, and the presence of sugar can be proved by suitable chemical tests. A root-hair is comparable to such a bag. Its fluid contents (cell-sap) correspond to the sugar solution in the bag, while the available plant-food, or weak solution of mineral substances in the soil, corresponds to the water outside the bag. As the amount of liquid plant-food diffusing *into* the hair is greater than the amount of cell-sap diffusing *out*, it is clear that the hair will be kept in a swollen or *turgid* state. It does not burst, however, for some of its contents diffuse into the underlying parts of the root, and by this process the **crude sap,** or solution of plant-food absorbed from the soil, ultimately reaches the woody strands of the vascular cylinder. Thence it passes along similar strands through the stem and into the leaves.

The liquid that diffuses into the soil from the root-hairs is slightly acid, partly because it contains in solution carbon dioxide, which is being breathed out, and partly because it contains certain vegetable acids. This liquid helps to dissolve the particles of soil, and we can therefore say that roots help to prepare plant-food. If a polished slab of limestone is sunk in a flower-pot containing a plant and left for some weeks, the roots of the plant will spread out on the polished surface, and, by dissolving a film of limestone, etch their own outline upon it.

In a good many cases the root serves as a **storehouse of nutriment** that the plant can draw from when necessary. Good examples are afforded by the swollen tap-roots of turnip, carrot, parsnip, radish, and sugar beet. In the last case the stored material is in the form

of a solution of sugar. This is the source of *beet sugar*, now so largely used to replace the *cane sugar* derived from the sugar cane.

Water Culture.—A sprouting bean may easily be suspended so that its radicle hangs in a vessel of water. If certain substances are dissolved in the water the plant will continue growing, its leaves will turn green, and it may even produce flowers and fruit. The substances which the water should contain—though in very weak solution—are chloride of potash, nitrate and phosphate of lime, sulphate of iron, and sulphate of magnesia.

By this method of *water culture* is learnt what substances plants require, and what they do not require, to be supplied them through their roots. It is thus proved that the presence of potash, lime, magnesia, iron, nitric acid, phosphoric acid, and sulphuric acid in the soil is absolutely *essential to the growth* of agricultural plants.

STEMS

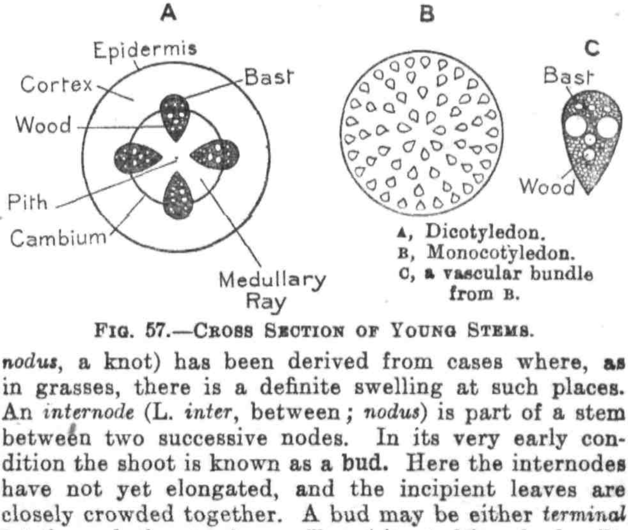
Characters of Stems.—The plumule of many seedlings grows vertically upwards as the primary shoot, and obviously consists of an axis, the **stem**, bearing flattened expansions, the **leaves.** That a stem should thus bear leaves is one of its primary characters, while an ordinary overground or *aerial* stem grows towards the light, and, when young, is green from the presence of chlorophyll.

One or two structural points also require notice. As already mentioned (p. 145), the delicate growing point at the end of a stem does not possess anything comparable to a root-cap, nor is a young stem traversed by a central vascular cylinder like that found in a root. Wood and bast fibres are associated in compound strands, known as **vascular bundles,** in each of which the wood is nearer the centre of the stem than the bast. This arrangement is technically known as **collateral,** bast and wood, in any one bundle, being on the *same* radius as seen in a cross-section, while in a young root the wood and bast are disposed *radially*—*i.e.*, on different radii (p. 145).

It is convenient to notice here that in the young stem of a Dicotyledon the vascular bundles, as seen in the cross-section, are arranged in a ring, while in the stem of a Monocotyledon, whether young or old, they are scattered. In the former, too, there is an actively dividing layer **(cambium)** of thin-walled cells, by which thickening is effected.

We have seen (p. 145) that branch roots arise deeply within the tissues of the parent root. This is not the case with branch-stems, and it must be added that each of these arises in the **axil** of a leaf—*i.e.*, in the upper angle between the base of the leaf and the stem.

Nodes and Internodes.—The regions of a stem from which leaves grow out are called **nodes.** The name (L.



A, Dicotyledon.
B, Monocotyledon.
C, a vascular bundle from B.

FIG. 57.—CROSS SECTION OF YOUNG STEMS.

nodus, a knot) has been derived from cases where, as in grasses, there is a definite swelling at such places. An *internode* (L. *inter*, between; *nodus*) is part of a stem between two successive nodes. In its very early condition the shoot is known as a **bud.** Here the internodes have not yet elongated, and the incipient leaves are closely crowded together. A bud may be either *terminal* (at the end of a stem) or *axillary* (situated in a leaf-axil). Both are well seen in a branch of horse chestnut after the leaves have fallen. Such winter buds are destined to form the shoots of the following year.

Kinds of Stem.—We can broadly distinguish between overground or aerial stems. and underground or

subterranean stems. Among aerial stems the most typical is the *erect* kind, which grows straight into the air. But there are many other sorts, such as *trailing*, *creeping*, and *climbing* stems. **Climbing stems** are particularly interesting, because they enable a thin stem to advantageously display its leaves to the sun and air without the expenditure of material necessary in the case of erect forms, though some of these—*e.g.*, grasses—by adopting the hollow pillar principle make a small amount of material go a long way. The means of climbing are very diverse. In ivy we find adventitious roots growing from the stem for this purpose. *Twining* stems, which wind round and round a support, are exemplified by hop, convolvulus, and dodder. Briars climb or rather scramble by means of hook-like prickles. And we may

FIG. 58.—STOLON OF CARNATION.

also find slender sensitive *tendrils*, as in the vine, Virginia creeper, and pea. In the two first-named plants the tendrils are modified parts of the stem, while in the pea they are specialized parts of the foliage leaves.

A **stolon** is a branch of the stem growing out from a leaf axil just above the ground (fig. 58), extending almost horizontally along the surface, and developing roots and leaves where it comes in contact with the soil. In time the connecting part of the stolon dies, and an independent plant results. Gardeners imitate this in the operation called 'layering,' when they bend down a branch from a shrub, and peg it to the soil, thereby causing it to develop roots, and so to form a fresh plant. Gaps in shrubberies can thus be filled up from the shrubs already present. The currant and gooseberry give off stolons, as also do the creeping buttercup

and white clover. Various grasses are enabled to rapidly extend, owing to their property of developing stolons, which are admirably adapted for insinuating their slender extremities between other pasture plants, and rooting at intervals. Plants that produce stolons are termed *stoloniferous*. To get a good idea of stolons, examine the beautiful prostrate shoots sent out by white clover (fig. 82), or by the creeping buttercup.

The **runner** is a long slender stolon, which, having attained its full length along the ground, strikes root from the tip, where it develops a new plant (fig. 59). A parent strawberry plant, if allowed room, will thus develop around itself, by means of runners, a number of offspring. As the runners die these offspring become separate plants, capable of repeating the process.

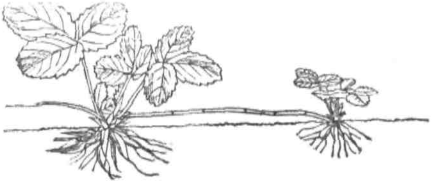


FIG. 59.—RUNNER OF STRAWBERRY.

We next come to **underground** or **subterranean stems**, many of which are familiarly called 'roots.' A potato is known to bear 'eyes,' and when potatoes are cut into sets for planting, the gardener takes care to cut in such a way that each set shall have an 'eye' or two.

The 'eye' is really a leaf-bud, as may be proved by examining a sprouting potato, and careful examination will show that it grows from the axil of a small scale-like leaf. Consequently the potato is a stem; that form of underground stem called a **tuber**, which is really a swollen branch. Other examples of tubers are seen in the Jerusalem artichoke and earth-nut.

Next, examine an onion freshly drawn from the ground. The fibrous roots are seen growing downward, and the edible part of the plant—popularly, the 'root'—is found to consist of the thick whitish fleshy

bases of leaves overlapping each other around a very short axis or stem (the 'plate' or disk), the internodes of which remain undeveloped. Such a structure is termed a **bulb**, and other examples are afforded by hyacinth and lily (fig. 60). A hyacinth growing in water in a glass shows clearly the distinction between the bulb and root. It may be asked how the glass - cultivated hyacinth gets the food wherewith it develops its stem and sweet-smelling flowers. The answer is that the food is stored up in the bulb. The 'solid bulbs' or **corms** of crocus and cyclamen mostly consist of a thickened stem, with some scaly leaves on the outside.

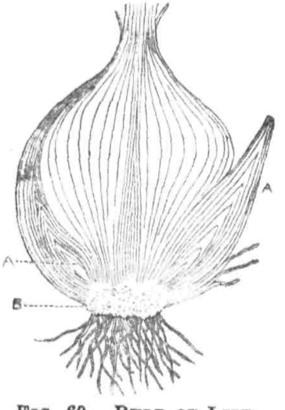


Fig. 60.—Bulb of Lily.

A, buds or young lateral bulbs.

B, plate or disc (the true stem) from which root-fibres grow down.

The term 'bulb' is often applied, but not correctly, to the turnip and the mangel. These are really bulb-shaped roots.

Many plants possess an elongated underground stem which grows horizontally or obliquely in the soil, sending out adventitious roots from its under surface and leaf-buds from above. Such stems vary much in thickness, according to the species of plant, but they are all included under the general name of **rhizome (fig. 61)** or **root-stock** (fig. 62). A stout, thickened form is seen in the horse-radish and the primrose, a much slenderer type in the couch grass, and an intermediate variety in the mint. When the leaves of a primrose die down as the summer advances, the root-stock still lives beneath the ground. Moreover, it very slowly travels along, for, as its front end grows forward its hinder part gradually decays.

The different kinds of what are termed creeping, running, or scaly 'roots' are all varieties of the rhizome

or root-stock. They rapidly extend through considerable portions of the soil, and, when they have once got a hold of the land, are very difficult to extirpate. They are always *perennial*—that is, they go on living from year to year—so that they continue alive in the soil through the winter, at a time when there may be no indication of their presence above ground. At every

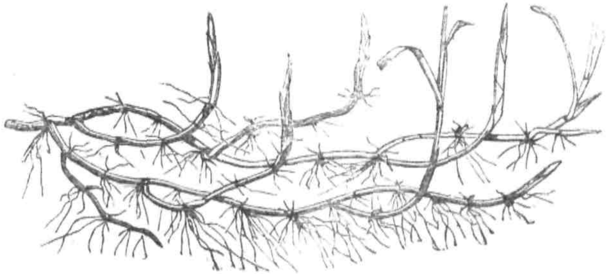


FIG. 61.—UNDERGROUND STEMS AND VERTICAL LEAF SHOOTS OF COUCH GRASS.

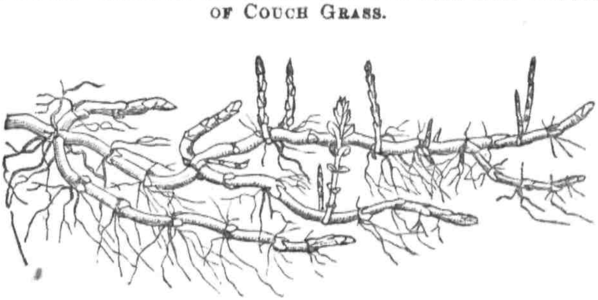


FIG. 62.—ROOTSTOCKS, OR CREEPING UNDERGROUND BRANCHES, OF MINT.

joint of these subterranean stems buds are produced, some of which grow up above the ground and bear leaves, flowers, fruit, and seed, whilst others form new underground shoots. In this way these structures form a dense bed or layer of interlacing stems beneath the surface of the ground. To cut them to pieces by the hoe or plough is useless, for it only serves to establish

new centres of growth, as every little portion bearing a bud is capable of individual development. Where land is infested by such underground stems, the only remedy is to pull them bodily from the soil. This is the kind of work which the scarifier does upon land foul from the presence of couch grass, some of the slender rhizomes of which can often be pulled out many yards in length.

Although the underground stem (fig. 61) of the couch grass is a pest upon arable land, the same kind of structure may, under special circumstances, be applied to useful purposes. Thus, the slender creeping stem of the sand sedge is valuable for binding together the loose sands of the seashore.

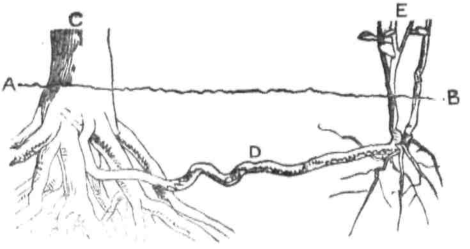


FIG. 63.—SUCKER OF ELM.

AB, ground line. D, sucker.
C, trunk of elm tree. E, young elm shoots.

An underground branch growing obliquely towards the surface, on reaching which it develops roots and leaves, is called a **sucker** (fig. 63). Examples may be seen around the rose, the raspberry, the elm tree, and other plants, which are incorrectly said to multiply 'by the root.' With the spade, remove the soil from such a sucker, and it will be seen to be only a creeping branch underground. As the sucker rots, the plant it produced becomes independent. A gardener accelerates this independence by cutting through the sucker with the spade. In doing this he propagates the plant 'by division.'

The various modifications of the stem that creep either along or beneath the surface of the ground should

be carefully studied by the cultivator. From their position they are frequently overlooked or ignored, whereas the vegetation that takes place *in* the soil is quite as important as that which is conspicuously developed above it.

Functions of Stems.—The chief uses of the stem are to display the foliage leaves to best advantage as regards sun and air; to display the flowers so as to give them a good chance of cross-pollination; and to dispose the fruits in such a way that the seeds may be dispersed by various agencies. It also serves as a means of communication between roots and leaves, and frequently acts as a storehouse of food. The last function is most obvious in the case of underground stems. In many cases, too, the stem plays an important part in **vegetative reproduction**, where propagation takes place without the agency of seeds, as by stolons, runners, suckers, etc.

LEAVES

Characters and Kinds of Leaves.—All leaves are appendages of the stem, taking origin at the nodes, and, in the large majority of cases, flattened in shape.

The following kinds of leaf are recognized:—

(1). *Scale-leaves.*—These are especially characteristic of underground stems. They are well seen in the potato tuber (p. 151), and in some bulbs, such as those of lily and tulip (scaly bulbs), serve for the storage of food.

(2). *Foliage-leaves.*—These are the ordinary green leaves of plants, and will be considered in some detail.

(3). *Bract.*—This name is applied to simple scale-like leaves in the axils of which flowers arise. Obvious examples are seen in Composites and Umbellifers.

(4). *Flower-leaves.*—These make up most of the flower, and will be dealt with in the next chapter.

Characters and Kinds of Foliage-leaves.—Examination of foliage-leaves from dicotyledonous plants will show the presence of some or all of the following parts: (*a*) **an expanded blade or lamina,** (*b*) **a leaf-stalk or**

petiole, (*c*) a **sheath** that clasps the stem, (*d*) outgrowths known as **stipules**, at the junction of petiole and sheath.

Sessile leaves possess no stalk, and a leaf devoid of stipules is said to be *exstipulate*.

The leaves of dicotyledons vary greatly in arrangement and shape, but in all cases we shall find the result to be exposure of surface to sun and air without undue overlapping. They are said to be **alternate** when only one is attached to a node, **opposite** when there are two.

A very interesting case is afforded by **rosette-plants,** such as daisy, dandelion, and plantain, where the internodes of the stem are undeveloped, so that the leaves are crowded together. Examination of one of the plants named will show that the leaves are so arranged as to take full advantage of air and light, while at the same time the surrounding plants are shaded and killed. Anyone who has removed a plantain or daisy plant from a lawn must have noticed the bare patch due to this cause.

In **simple** leaves the blade is one piece, while in **compound** leaves it is divided into *leaflets*. The latter are either *palmate*, when all the leaflets are attached to the end of the petiole (*e.g.*, horse chestnut), or *pinnate* when they are disposed in a feather-like way, as in rose and many leguminous plants.

The leaves of monocotyledons are usually simple and stalkless. The sheath is commonly well developed, and a scale-like outgrowth, the **ligule**, is often found on the upper side at the junction of blade and sheath. This is well seen in grasses (fig. 117), where the characters of the ligule are of great importance in helping to distinguish between different species.

Structure of Foliage-leaves.—Conducting strands of wood and bast—*i.e.*, vascular bundles—pass from the stem through the leaf-stalk (if present), and branch out in the flattened blade, where they are commonly known as 'veins.' In monocotyledons the chief veins are more or less parallel, while in dicotyledons they soon break up into a complex network.

When a section through the blade of a leaf (fig. 64) is examined through a microscope, it is seen that the

upper part consists of rows of elongated cells placed side by side—**palisade cells** they are called. As the lower surface is approached the cells are more loosely aggregated, so that spaces—air-spaces—exist between them. Both the cells in this **spongy tissue** of the leaf and the palisade cells are green, owing to the fact that part of their protoplasm consists of **chlorophyll granules**, permeated by the complex substance known as **chlorophyll** (*see* p. 136). Palisade cells

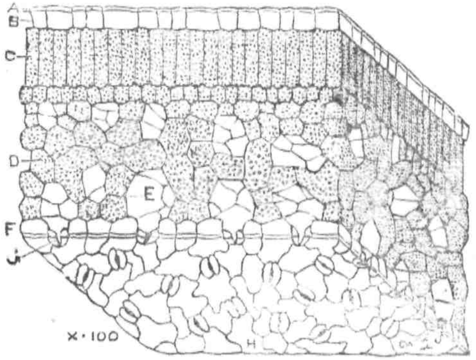


FIG. 64.—SECTION OF A LEAF (magnified).

A, cuticle, B, epidermal cells, of upper surface.
C, palisade cells.
D, cells of spongy tissue.
E, intercellular spaces, or air cavities.
F, epidermal cells of under surface.
G, stomata opening on surface of
H, epidermis, or skin, of lower surface.

and spongy tissue are together known as **mesophyll**, which is traversed by the **vascular bundles** of the leaf (not shown in fig. 64). The reason the under side of the leaf is usually paler in colour than the upper surface is that the green cells of the upper side are more closely crowded together. Over the whole leaf there extends a thin transparent skin, the **epidermis**. But the epidermis is not entire, for it is dotted with innumerable minute apertures called

stomata (Gr. *stoma*, a mouth), each *stoma* being formed by a pair of kidney-shaped cells, with their concave sides towards each other. By the straightening or bending of these 'guard cells,' the size of the stoma is controlled, and it is dependent upon external conditions of light and moisture. As a rule the stomata are far more abundant on the *under* than on the upper face of the leaf.

Functions of Foliage-leaves.—The most important function of foliage-leaves is **carbon assimilation.** Their chlorophyll granules are able to use the energy of sunlight in bringing about a reaction between the carbon dioxide absorbed from the air and the water that has been taken from the soil, with the formation of organic matter (*see* page 143). The intercellular spaces of the leaf are full of air, and directly continuous with the exterior by means of the stomata. The mesophyll cells can therefore readily obtain the carbon dioxide they require for their constructive work, and can as easily get rid of the oxygen formed as a by-product.

The first *visible* product of assimilation in the leaf is starch, as can readily be proved by soaking in iodine solution a leaf that has for some time been exposed to sunlight, when it turns to a blue-black colour This is a well-known laboratory test for starch.

Foliage-leaves also play an active part in **breathing** or **respiration,** during which free oxygen is taken up and carbon dioxide eliminated (*see* p. 143). The intercellular spaces of the leaf obviously promote this function by supplying air to the mesophyll cells.

Transpiration.—If some freshly-gathered leaves are put under a cold dry tumbler, the inner surface of the tumbler becomes covered with moisture. This is because the leaves are constantly giving up water vapour. They at length wither—*i.e.*, lose their turgidity—because they get no fresh supply of moisture. The evaporation of moisture from leaves, in the manner described, is called **transpiration.** The quantity of water which thus passes through a plant, from the soil to the atmosphere, is very great. A maize plant was observed to give off between May 22 and September 4, a period of 16 weeks, as

much as 36 times its weight of water. Barley, beans, and clover, during 5 months of their growth, transpired more than 200 times their (dry) weight of water. A large oak tree will transpire from 10 to 20 gallons of water in a day. Land under crop gives up more water per acre than an adjacent bare fallow, because of transpiration. In a hot, droughty summer the land around trees suffers most, on account of the great demand for moisture to supply that lost by the leaves. If laid out, side by side, the leaves of a big tree would cover several acres. A sunflower, 5 feet high, will transpire from a pint to a quart of water during a hot summer day. As sunflowers are of quick growth they are sometimes planted around cottages in swampy situations to diminish the risk of ague.

A few words are here necessary regarding the physiological meaning of transpiration. We have seen that roots absorb a very weak solution of mineral substances from the soil (p. 147), and this crude sap travels up to the leaves through the wood of the vascular bundles. As a considerable amount of mineral matter is used up in the constructive processes, especially when active growth is taking place, a constant stream of crude sap is essential. We may therefore look upon transpiration as a means of getting rid of the superfluous water in this crude sap.

By ferment action the starch formed in leaves is converted into a soluble form, largely sugar, and the **elaborated sap**, containing this and other products of constructive activity, is carried from the leaves to places where it is needed. In this conduction the bast of the vascular bundles plays an important part.

DURATION OF LIFE

Annuals.—Many plants spring up from the seed, produce their leaves and flowers, fruit and seed, all within the space of one year, and then die. Such plants are called **annuals**, and examples are seen in **wheat, barley, oats**, rye, brome grasses, **buckwheat, beans, peas, vetches**, and **'trifolium.'**

Biennials.—Another group of plants is distinguished by requiring two years, or at least two seasons, for this work. During the first season they grow up from the seed and develop what are called their *vegetative* organs—the organs of growth. Then there ensues a period of rest, followed by the development of the *reproductive* organs—that is, the flowers, producing fruit and seed. Such plants are called **biennials,** because they need a portion of two years to accomplish the changes between sowing and fruiting. Examples are seen in the so-called 'root crops'—turnips, swedes, cabbages, and their allies; and in parsnips, carrots, celery, lettuce, mangel, and beetroot.

Both annuals and biennials are usually prolific producers of seed. The effort involved in forming so large a quantity of seeds at one time is so great that it kills the plant. But, though the individual dies, ample provision is at the same time made for the preservation and perpetuation of the *species*, for each seed contains a new plant in miniature.

One reason why the production of seed is so exhausting to the parent plant is that each seed contains a store of very rich food which the parent has had to supply. A seed, therefore, is a reservoir of nutriment, and man cultivates seed-bearing plants in order that he may step in and secure the food in the seed, either for himself, or for his domesticated animals.

During the process of ripening there is a steady *migration* of nutrient material from the other parts of the plant into the seed. From the leaves and stem of a wheat or bean plant, for example, most of the nutritious matter is carried away in solution and deposited in the seed. During the later days of their lives, such plants cease to take food from the soil or air, and they are capable of completing the ripening of the seed provided they can get a sufficient supply of water. Wheat, cut before it is dead ripe, will complete the ripening of the grain while standing in stook.

In the case of *biennials* there is a resting period between the two seasons of growth. Let turnip seed, for example, be sown in June, and by the autumn a

well-shaped root will be formed. This root may be left in the field through the winter, and in the following spring it sends up leaves and flowers, produces fruit and seed, and then dies. But a great change has taken place in the root, for it is now small and shrivelled. The root, indeed, serves as a temporary reservoir of the nutriment which is afterwards consumed in forming the seed. The reason the cultivator grows such crops as turnips, carrots, parsnips, mangels, etc., is that he can interfere at this resting stage, and utilize the store of food for himself or his live stock.

It is not necessary that the roots of biennial crops, intended for the production of seed, should remain in the ground all the winter. They may, if desired, be taken up, and planted out again in spring. By this means it is possible to make a selection, and to reserve only the most desirable specimens for the growth of seed.

Perennials.—This name is given to plants that live for more than two years. Examples are seen in sainfoin, lucerne, white clover, furze, yarrow, prickly comfrey, plantain, asparagus, and pasture grasses. Also, in the gooseberry, currant, strawberry, raspberry, plum, cherry, apple, pear, and timber trees. In such perennial plants as lose their leaves during winter, there is, before the fall of the leaf, a migration of nutrient materials from those organs into the stem (certain regions of a tree trunk, for example), which serves as a reservoir. The leaf-buds of deciduous trees are formed in the autumn, and when they commence to open in the spring, their first food is derived from the reservoir of nutriment in the stem. It is because this supply of ready-made food is close at hand that leaf-buds expand so rapidly under the influence of the increasing temperature of spring. Leafless trees should be examined for their buds in the winter. Those of the beech, ash, horse-chestnut, and willow are very beautiful, but the buds are equally noticeable on other timber trees and on orchard fruit trees.

Various parts of the plant, it has been seen, may serve as **storehouses of nutriment.** The seed always contains a reserve of plant-food; in biennial plants, the

root acts as a reservoir; and, in perennials, the stem. Many such reservoirs have a special interest, because they are diverted by man to his own purposes. The tuber of the potato is stored with food, chiefly starch. The bulb of the onion and the young shoot of the asparagus are other examples.

CHAPTER XI.

STRUCTURE AND FUNCTIONS OF PLANTS—FLOWERS, FRUIT, AND SEEDS

FLOWERS

Structure and Function of Flowers.—The flower is a shoot that is specialized in relation to the formation of seeds. It consists of **flower-leaves** of various kind, crowded together on a shortened region of the stem known as the **floral receptacle** or **torus**, which is the swollen end of the **flower-stalk** or **peduncle**. This crowding of flower-leaves on a short thick piece of stem is due to suppression of internodes. A comparison may be made with the rosettes of foliage-leaves seen in such plants as daisy, dandelion, and plantain (*see* (p. 156).

The flower of a **buttercup** is a simple and convenient type with which to make a start. Four different kinds of flower-leaf will be found attached to the receptacle (fig. 65). Beginning at the outside, these are: (1) Five small green **sepals** arranged in a circlet or whorl, and collectively termed the **calyx**. (2) A whorl of five large yellow **petals** alternating with the preceding, and together constituting the **corolla**. (3) A large number of thread-like **stamens**, each with a thickened end. (4) A number of small flattened **carpels**, making up what is known as the **pistil**.

The function of the flower is to produce seeds, and as only the stamens and carpels are *directly* concerned

with this, they are conveniently termed **essential organs**, while the investing corolla and calyx together constitute the **perianth.** The relative positions of these different kinds of flower-leaf can be indicated in a ground plan or **floral diagram** (fig. 65, B).

A closer examination of the essential organs here becomes necessary. A stamen is seen to consist of a stalk or **filament**, bearing a thickened two-lobed **anther.** When the latter is ripe it splits open, and fine yellow dust (the **pollen**), escapes to the exterior. It consists of minute **pollen-grains**, which may be regarded as *male*.

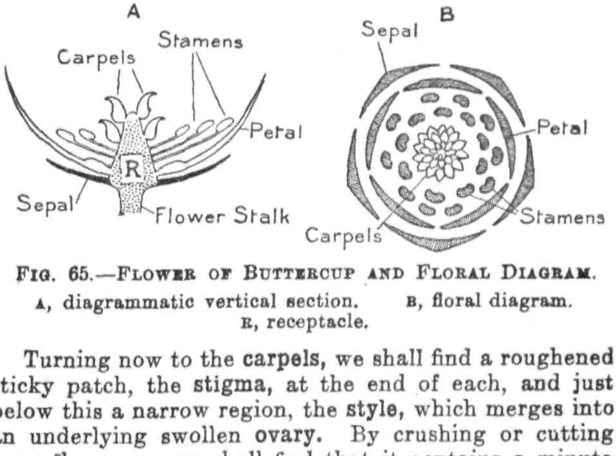


FIG. 65.—FLOWER OF BUTTERCUP AND FLORAL DIAGRAM.
A, diagrammatic vertical section. B, floral diagram.
R, receptacle.

Turning now to the **carpels**, we shall find a roughened sticky patch, the **stigma**, at the end of each, and just below this a narrow region, the **style**, which merges into an underlying swollen **ovary.** By crushing or cutting open the ovary we shall find that it contains a minute rounded body. This is an **ovule**, which, under favourable circumstances, may become a seed. Examination of prepared longitudinal sections through ovules will show the following parts: (1) A stalk **(funicle)** attaching the ovule to the ovary, and serving to convey nourishment to the developing seed. (2) An external skin **(integument)** extending from the base of the ovule to its tip, where, however, a minute aperture, the **micropyle** (fig. 66) is left uncovered. (3) A cellular mass, the **nucellus**, making up the interior of the ovule. (4) A

clear egg-shaped bag, the **embryo-sac,** within the nucellus, adjacent to the micropyle. (5) A spheroidal **egg-cell,** or *female cell* inside the embryo-sac, close to the micropyle. The remaining contents of the embryo-sac, for our present purpose, may be neglected.

Pollination and Fertilization (fig. 66).—The stigma is rough and sticky, so that pollen-grains may adhere to it. Their transfer is technically known as **pollination,** and when it has taken place the stigma is said to be *pollinated.* This is an essential preliminary to the formation of seeds. In cucumber and vegetable marrow, for instance, the flowers are of two kinds—(*a*) *male,* or *staminate,* devoid of pistil, and (*b*) *female,* or *pistillate,* devoid of stamens. If pollen is prevented from reaching the stigmas of the female flowers, no fruit will be set and no seeds will be formed. We must therefore enquire what takes place after pollination has been effected. It will be found that after reaching the stigma a pollen - grain swells up and germinates, sending out an excessively delicate **pollen-tube,** the tip of which bores through the style, enters the ovary, and makes its way to the micropyle of an ovule. A minute quantity of the living matter (*protoplasm*) with a *male nucleus* (derived from one of two nuclei contained in the pollen-grain) passes into the egg-cell, and the male nucleus fuses with the *female nucleus* which this contains. The process is termed **fertilization** (or *impregnation*), and the egg-cell is said to be *fertilized* (or *impregnated*). It now undergoes numerous divisions to form an **embryo** or **plantlet,** while the rest of the ovule becomes the remaining part of

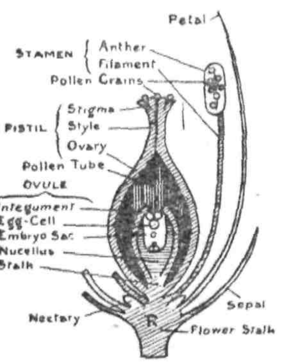


FIG. 66.—VERTICAL SECTION OF FLOWER, ILLUSTRATING POLLINATION AND FERTILIZATION. R, receptacle.

the seed. The ovary also undergoes changes, which convert it into a **fruit.** Broadly speaking, therefore, a fruit is a matured ovary and a seed a matured ovule. The fusion of male nuclear matter with female nuclear matter that constitutes fertilization is the essential part of **sexual reproduction,** alike in plants and animals.

Flowers and Insects.—Let us now return to the yellow **corolla,** which makes the buttercup flower so conspicuous, and enquire the meaning of this. Near the narrow base of each petal a small pit can be seen, covered over by a yellow scale. A little care will enable us to prove that the pit contains a sweet fluid **(nectar)**, and is, in fact, a **nectar-gland (nectary),** while the scale is a **nectar-cover** that prevents the secretion from being washed away by rain. By watching growing buttercups in sunny weather we shall find various small insects crawling about the flowers, some licking the nectar, and others devouring the nutritious pollen, of which the very numerous stamens produce a great quantity. Observations of other kinds of conspicuous flowers will show that they, too, are visited by insects, to which they offer similar attractions. It would seem, therefore, that by the possession of nectar and superfluous pollen the buttercup is adapted to the visits of insects, and the conspicuous corolla, advertising desirable booty, attracts their attention. As a single buttercup plant bears many blossoms, and numerous plants often grow near together, the collective colour effect is very considerable. The **odour** of many flowers constitutes another means of attracting insects, and even buttercups probably possess a honey-like smell perceptible to these little creatures.

It may be taken as a general rule for temperate climates that conspicuous flowers—many of which exhale a distinct odour—attract insect visitors, *i.e.*, are insect-loving **(entomophilous),** and provide food for their guests. Important services are rendered in return, as will now be explained.

Self- and Cross-Pollination and Fertilization.—The flowers of buttercups and most other flowering plants are *bisexual*, containing both stamens and carpels. It

follows, therefore, that pollination of the latter, and its sequel, fertilization, may be effected either (1) by pollen from the same flower, or (2) by pollen from some other flower of the same species. That is to say, either self-pollination or cross-pollination may take place, to be followed by self-fertilization or cross-fertilization, as the case may be. It appears that healthier and more vigorous seeds are produced by crossing, and this explains why flowers lay themselves out to attract flying insects, for these unconsciously carry pollen from one blossom to another, and often effect cross-pollination. The buttercup flower attracts a miscellaneous set of insects, and as its outer anthers are ripe at about the same time as the stigmas become receptive, insect visitors do not regularly and automatically effect crossing, as in some other cases.

The green **calyx** of the buttercup flower has nothing to do with pollination, but serves as a protection to the more delicate internal flower-leaves, especially before the bud expands.

One or two other characters of the buttercup flower require notice. In the first place, its sepals and petals are regularly arranged with regard to a set of imaginary lines radiating from the centre, like the spokes of a wheel. The flower is therefore said to display **radial symmetry**, or to be **regular.** In the second place, it will be seen on examining a vertical section of the flower that sepals, petals, and stamens all grow out from the receptacle *below* the pistil. In technical language, the flower is **hypogynous.** In this case the pistil is said to be **superior,** and the calyx **inferior.**

For comparison with the buttercup it will be instructive at this stage to consider a few other types of flower. Take, for example, any of the **cross-bearing** or **cruciferous** flowers, such as wallflower, cuckoo flower, cabbage blossom, charlock, hedge-garlic, etc. These are obviously regular, and sufficiently conspicuous to suggest that they are adapted to the visits of insects, which is, in fact, the case. It is convenient to distinguish between the *back* and *front* of a flower, nearest to and furthest from the main axis respectively. The terms

posterior and **anterior** are applied to flower-leaves at the back or front, as the case may be, while those at the sides are **lateral.**

The arrangement of parts in the cruciform flower is as follows: (1) **Calyx,** of four distinct sepals in two alternating whorls of two each, an outer of anterior and posterior sepals, and an inner of lateral sepals. (2) **Corolla,** of four distinct petals, arranged obliquely like a Maltese cross, whence the name 'cruciferous' (cross-bearing) as applied to plants bearing such flowers. (3) Six **stamens** in two whorls, an outer made up of a short lateral stamen on each side, and an inner of two pairs of long stamens, placed back and front respectively. (4) A **pistil** composed of two lateral carpels fused together. The double stigma indicates what has taken place. Stamens and petals are hypogynous, pistil superior, and calyx inferior, as in buttercup (*see* p. 166).

When calyx, corolla, and stamens have been removed some little swellings will be observed on the receptacle. These are the **nectaries.** Insect visitors alight on the platform afforded by the corolla, and probe for nectar, often effecting crossing as they go from flower to flower. An interesting explanation can be given of the reason for long and short stamens in the crucifers. The anthers of the former protrude from the flower, so that their pollen easily adheres to insects and often effects crossing. The anthers of the short stamens, on the contrary, only reach the level of the stigma, thus securing self-pollination in the event of crossing not having taken place.

Cruciferous flowers, as compared with buttercups, are an example of reduction in the number of stamens, and even more so in the number of carpels, while the latter are fused together, an advance on the simpler state of things exemplified by the buttercup. A pistil is termed **apocarpous** when its carpels are not united, **syncarpous** when they are more or less fused together.

As a third common type of flower, characteristic of leguminous plants, we may take that of the **pea** or **bean,** and shall at once be struck by the fact that it is not regular, but two-sided, or, to use the technical

term, **irregular** (figs. 67 and 68). It is a case of two-sided or **bilateral symmetry,** as contrasted with the radial symmetry of buttercup and wallflower. This means more marked adaptation to the visits of insects, especially those, such as bees, of higher kind, with well-developed sight and smell, and elongated mouth-parts, capable of probing deeply for concealed nectar.

The parts of the flower are as follows: (1) A green cup-shaped **calyx,** made up of five fused sepals, one of which is anterior. (2) A large, showy, butterfly-shaped (*papilionaceous*) **corolla,** composed of five petals, to which fanciful names are given. They are: (*a*) a large upright

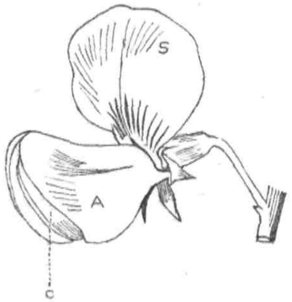


FIG. 67.—PEA BLOSSOM (with papilionaceous corolla).

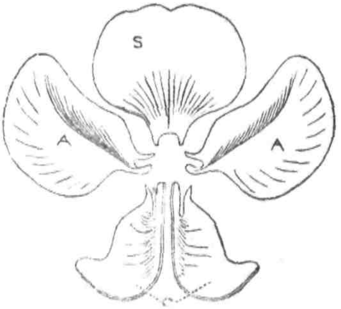


FIG. 68.—PARTS OF A PAPILIONACEOUS COROLLA.

A, Alæ. C, Carina. S, Standard.

standard (*vexillum*) at the back, (*b*) a pair of **wings** (*alæ*), which serve as an alighting platform for insect visitors, and (*c*) an anterior **keel** (*carina*), which shelters the essential flower-leaves, and consists of two petals with distinct stalks but united limbs. (3) Ten **stamens,** consisting of two whorls of five each. A posterior stamen is quite distinct from the rest, but the stalks of the remaining nine are fused into a tube, surrounding (4) the **pistil,** which is termed *simple*, because it consists of a *single* carpel, that matures into the familiar pod. The latter is of considerable interest, because it shows that carpels are really *folded leaves*. By holding a young pea

pod up to the light we shall see that there are two thickened edges, the peas or seeds being next one of these. Carefully split open the pod along this edge (the *ventral suture*) and spread it out, when it will not be difficult to realize that we have before us a modified leaf, bearing seed along its edges. The thickened edge of the pod away from the seed is clearly the midrib of this leaf. An even clearer demonstration of the real nature of carpels is furnished by marsh marigold (*Caltha*), columbine (*Aquilegia*), or larkspur (*Delphinium*), all relatives of the buttercup.

The stigma and anthers of pea or bean are so close together in the tip of the keel that self-pollination would seem inevitable. As in a great many other flowers, however, this is for some time prevented by a simple device. The stigma and anthers do not mature simultaneously. Such a flower is termed **dichogamous**, and it is clear that either the anthers may first be ready (*protandrous*) or else the stigma (*protogynous*). The former is true for pea, bean, and the large majority of cases.

Suppose, now, that a bee, attracted by the colour and fragrance of the blossom, alights upon the wings and clings to the standard. The pressure exerted will cause first the stigma and then the anthers to protrude from the tip of the keel. If the under side of the bee has already been dusted with pollen from a flower previously visited some of this will probably be transferred to the stigma, and then a fresh supply of pollen will be brushed from the anthers, and very likely carried to another flower.

In pea and bean the nectar is secreted at the base of the pistil within the staminal tube, and this explains why the posterior stamen is free. The proboscis of the visitor can be thrust into the tube on one or other side of the free stamen. (In some flowers—*e.g.*, gorse or furze—related to the pea and bean—there is no nectar, and only pollen is offered to insect visitors. In such cases the posterior stamen is not free, and the filaments of all ten stamens are fused together.) Upon the standard can be seen a number of coloured streaks.

which converge below, and, as it were, point out the way to the nectar. Streaks, dots, and other markings of this kind are known as **nectar-guides**, and they may be seen in very many different kinds of flower. Pansy, forget-me-not, pelargonium, and azalea are striking instances.

Examination of a vertical section through a pea or bean flower shows that sepals, petals, and stamens do not—as in buttercup or wallflower—grow out from the receptacle *below* the pistil. The receptacle, indeed, instead of being conical, is broadened out into a very shallow cup, to the centre of which the pistil is attached, while the sepals, etc., spring from the margin. The flower is not, therefore, hypogynous (*see* p. 166), but **perigynous**—*i.e.*, the sepals, etc., are grouped *around* the pistil, which, however, is not fused with the receptacle. Rose, blackberry, and cherry are more markedly perigynous than the pea or bean, for in them the receptacle is a comparatively deep cup.

A number of plants bear '**incomplete**' flowers, in which the perianth either consists of a single whorl (*e.g.*, beet and mangel) or is entirely absent (*e.g.*, hazel). Such flowers are small, greenish, usually odourless, and generally devoid of nectar. As might be conjectured from these characters, they are *not* adapted to insect visits, and in many of them pollen is transferred from flower to flower by the wind—*i.e.*, they are wind-loving (**anemophilous**). Self-pollination is also of frequent occurrence.

Dicotyledons and Monocotyledons.—In all the flowers so far described it will be noticed that the whorls of flower-leaves are mostly in twos, fours, or fives. This is one feature of the great group of **Dicotyledons**, which are further characterized by the ring-like arrangement of the vascular bundles in the young stem, net-veined foliage leaves, and two cotyledons in the seed.

Even a cursory examination of **liliaceous** plants (*e.g.*, lily, tulip, onion) and **grasses** will show that they do not conform to this type. In a lily or tulip we shall find three petal-like (*petaloid*) sepals, three petals, six stamens in two whorls of three each, and a pistil of three carpels fused together. In grasses the perianth

is much reduced, but the stamens are usually three in number. The foregoing belong to the group of **Monocotyledons,** in which many of the flower-leaves are in threes, the vascular bundles in the young stem are scattered, the foliage-leaves are parallel-veined, and the seed possesses but a single cotyledon.

Cross-Pollination and Cross-Fertilization.—Cross-pollination and its sequel cross-fertilization are secured by a large number of different devices, which have gradually come into existence by a process of evolution. The most certain method is exemplified by plants in which the flowers are **unisexual,** being either **staminate** (male) or **pistillate** (female). Sometimes these male and female flowers are found on different plants (**diœcious**), as in willow, or both may occur on the same plant (**monœcious**), as in hazel.

Pollen is transferred from one flower to another by various agents, of which wind and insects are the most important. In typical **wind-pollinated flowers**—*e.g.*, many trees and grasses—the stamens possess very slender filaments, to which the anthers are but lightly attached, so that they are moved by the least breath of air. The pollen is dry and easily scattered, sometimes being liberated by sudden spring-like movements of the stamens, as in nettles. The stigmas are commonly branched and hairy, protruding well out of the flower to catch the wind-borne pollen-grains. Wind-pollinated flowers are inconspicuous, odourless, and devoid of nectar.

Insect-pollinated flowers provide pollen or nectar, or both, for their visitors, which are attracted by various colours and odours, while structural arrangements of various kinds ensure, in greater or less degree, the transfer of pollen from one blossom to another during the visits received.

Examination of numerous types of insect-pollinated flower enables us to make out a series of specializations of increasing complexity, by which crossing is rendered more and more certain as the scale is ascended. Regular flowers, with free flower-leaves, yellow or white in colour, and readily accessible nectar, may be con-

sidered as comparatively unspecialized. The buttercup is a good example (*see* p. 162). Such flowers attract a miscellaneous set of short-tongued insects, which do not effect crossing with any certainty. Even in such cases, however, the fact that at least some of the anthers ripen before the stigmas have become receptive (or, more rarely, the converse) secures some amount of crossing.

From simple cases like those just indicated we can trace specialization along several lines, the net result being that the larger and more intelligent long-tongued insects (especially hover-flies, butterflies, moths, and bees) are attracted with greater frequency, while the more stupid short-tongued insects are excluded. At the same time the arrangements for reception of visitors render crossing more and more probable.

As already mentioned, yellow and white are the most primitive colours, though it must be added that the latter is also found in flowers adapted to attract moths, as it is conspicuous at dusk. Red and reddish-brown (as in pink and wallflower) attract butterflies, while blue and purple (as in larkspur and monkshood) attract bees. Bright blue, as in speedwells, is sometimes an adaptation to the visits of hover-flies.

Irregular flowers are more specialized than regular ones, as well seen in larkspur and monkshood, which are relatives of the buttercup. Other good examples are the butterfly-shaped blossoms of pea, bean, etc. (*see* p. 168), and the lipped or labiate flowers of foxglove, snapdragon, sage, and mint.

Fusion of parts, and deeply concealed nectar, also mark specialization. The union of petals in the labiate flowers just named is a case in point, such union giving rise to a tube, at the bottom of which nectar is usually found.

Specialized flowers are so constructed that an insect visitor is bound to touch anthers and stigma, and as this means economy of pollen some of the stamens can often be dispensed with. Among Monocotyledons, for example, the full number of stamens is six, as in lily, but the more specialized iris only possesses three, while

orchids, the most complicated of all flowers, usually have but one. The massing together of numerous flowers of the same kind greatly enhances conspicuousness and largely increases the chance of insect visits. Hence, in all probability, one important reason for the evolution of flower-groups, or **inflorescences,** in the majority of species. Obvious examples are afforded by foxglove, wallflower, lilac, elder, and cow parsnip. Small flowers, individually inconspicuous, when thus aggregated, collectively make up a mass of colour that is easily seen from a distance. The most notable case is that of Composites, such as thistle, dandelion, and daisy. What at first sight appears to be a single flower in plants of the kind is really an aggregate of numerous minute flowers or *florets.*

Striking colour-effects on a large scale are produced by association of numerous plants of the same species. Gorse, heather, and buttercup are good illustrations.

The massing together of flowers distinguished by some marked odour may also secure visits, even though there may be no particular colour-effect. The delicious fragrance exhaled by lime-trees, for example, attracts innumerable bees.

Artificial Pollination.—Pollen can, of course, be transferred by human agency, should the necessary insects be scarce or absent. When cucumbers, vegetable marrows, or melons, all forms with unisexual flowers, are grown in frames, the gardener often ensures pollination by 'dusting' the female flowers with the male ones. It also frequently happens that certain fruit-trees, such as peaches, apricots, and nectarines, come into flower before bees are abundant. In such cases it is usual for a small camel-hair brush to be used for transferring pollen.

This method is commonly employed for the production of new varieties, which often excel those previously existing. By selecting two plants of the same species, both possessing exclusive characters which it would be desirable to combine in the same plant, and by cross-fertilizing them and raising fresh plants from the seed, cultivators have been able to establish many of these. Some of

these *crosses* are of great commercial value, particularly in the case of cereals and potatoes. Many beautiful modifications of florists' plants have been in like manner originated.

Self-Pollination and Self-Fertilization. — Although cross-pollination and cross-fertilization are promoted in a great variety of ways, and the latter appears to be necessary at intervals for maintaining the vigour of the species, they are probably not of the paramount importance once supposed, for a large number of naturally produced seeds capable of germinating into healthy plants result from self-fertilization following self-pollination. This is especially true for unspecialized flowers like the buttercup, where the chances of cross- and self-pollination are about equal. It also frequently happens that self-pollination is provided for should failure of insect visits or other cause have prevented crossing. In foxglove, for instance, the purple corolla, to which the stamens are attached, falls off and drags the anthers over the stigma. And, as already mentioned, the short stamens of cruciferous flowers appear to be a special provision for selecting self-pollination (*see* p. 167). There are also many small flowers (*e.g.*, chickweed, groundsel, and wheat) where self-pollination is the rule rather than the exception. Dog-violet, wood sorrel, and some few other plants, even bear, at the end of the ordinary flowering season, small special flowers that never open (*i.e.*, are **cleistogamous**). The anthers of these produce a small number of pollen-grains, from which pollen-tubes grow directly into the stigma.

FRUITS AND SEEDS

Botanically speaking, a **seed** is a ripened ovule, containing a dormant embryo or plantlet, while a **fruit** is a matured ovary, containing one or more seeds. But in ordinary language the terms seed and fruit are much more loosely applied. Thus, a grain of wheat or rye is popularly called a seed, though it is really a fruit, being the matured ovary of a wheat or rye flower.

By scraping off a thin coat, corresponding to the wall of the ovary, the true seed is laid bare.

The cultivator employs the term 'seed' to denote 'that which is sown,' rather than to indicate the ripened ovule. It commonly happens, however, that the seed, as sown, is the true botanical seed, as is the case with cabbages, turnips, rape, mustard, cress, beans, peas, clover, and onions. In all these cases, the ripened ovule is sown.

But in the case of 'seed potatoes.' nobody could regard the tubers which are planted as true seed. In the case of the following crops, what the cultivator sows is really **the fruit and not the seed.** Umbelliferous plants, such as carrot, parsnip, celery, parsley, caraway. Composite plants, such as sunflower, yarrow, lettuce, endive, dandelion, chicory. Other plants, such as wheat, rye, buckwheat. Sainfoin is sown either as 'unmilled,' that is, the wrinkled pod containing the seed, or as 'milled,' the pod having been removed and the true seed alone being sown.

In yet other cases, the fruit, with something more is sown as the 'seed.' This is so in beetroot and mangel, as well as in barley and oats and most of the true grasses.

Kinds of Fruit.—True fruits are conveniently divided into *dry* and *succulent*, each of these groups being further subdivided. A few of the commoner kinds may here be considered.

A. Dry Fruits.—These are either *indehiscent* or *dehiscent*. In the former case the wall of the fruit gradually decays after sowing, in the latter it splits open to liberate the seed. I. **Indehiscent Dry Fruits.** (1) The **achene** is developed from a single carpel, its wall is of horny texture, and it contains but one seed. The buttercup flower produces a group of achenes. (2) The term **caryopsis** is applied to the fruits of cereals and grasses. It contains only one seed, like an achene, but differs from this in being derived from a syncarpous ovary—*i.e.*, it consists of more than one carpel. (3) The **nut** is a ripened syncarpous ovary, its wall is woody, and there is usually a single seed. Hazel is a good

example. II. **Dehiscent Dry Fruits.** (1) The **follicle** is a single ripened carpel, contains several seeds, and splits open along the side which bears these (*i.e.*, ventral suture). A flower of marsh marigold, columbine, larkspur, or monkshood, produces a group of follicles. (2) The **pod** or **legume,** characteristic of leguminous plants, chiefly differs from the follicle in the fact that it splits open along *both* sides. Pea, bean, broom, and gorse, will serve as examples. (3) Cruciferous plants possess a distinctive fruit, often known as a pod, which is termed a **siliqua** if long (fig. 69), and a **silicula** if short. It results from the ripening of a syncarpous ovary composed of two carpels (*see* p. 167). These have fused together by their edges, but the contained cavity is divided into two by the growth of a partition known as the **replum.** When the fruit opens the carpels separate from below upwards, leaving the seeds attached to the replum (fig. 69). The fruits of wallflower, cuckoo-flower, cabbage, turnip, mustard, and charlock are siliquas; those of shepherd's purse and candytuft siliculas. (4) The **capsule** is developed from a syncarpous ovary made up of two or more fused carpels. It opens in a variety of ways to liberate the seed. Examples are afforded by the fruits of poppy, chickweed, foxglove, primrose, scarlet pimpernel, lily, and tulip.

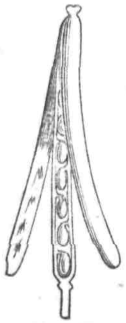


FIG. 69.—FRUIT (SILIQUA) OF A CRUCIFEROUS PLANT.

B. SUCCULENT FRUITS include many of the fleshy forms to which the term 'fruit' is most commonly applied in ordinary language. There are two chief types. (1) In the **drupe** or **stone-fruit,** such as plum, cherry, or peach, the hard wall of the single 'stone' is the innermost layer of the fruit, and the kernel is the seed. Blackberry and raspberry are aggregates of small drupes or *drupels.* (2) The **berry** contains a number of small hard seeds, the coats of which are thickened to form protective investments. Examples are grape, currant, and gooseberry.

Spurious Fruits.—The foregoing are *true* fruits—*i.e.*, matured ovaries, with their seeds—but a number of well-known fruits are termed 'false' or 'spurious,' because they include some other part of the flower in addition. The fleshy part of a strawberry, for example is the enlarged and juicy floral receptacle. In this case the small brown bodies scattered over the surface, and often supposed to be seeds, are the true fruits (achenes). Apple, pear, and quince are also spurious fruits, in which the 'pips' are the seeds, the core the matured ovary, and the flesh the developed floral receptacle. A good example of spurious *dry* fruits is afforded by the so-called 'seeds' of Composites, such as yarrow, dandelion, thistle, and sunflower. Such fruits superficially resemble achenes, and contain only one seed, but they are composed of *two* carpels, and their outermost layer is really the floral receptacle.

Dispersal of Seeds.—Some plants may be said to scatter their own seeds, as in broom, where the ripe pods suddenly burst open and fling them to a distance. In many cases the wind serves as an agent of dispersal, which is but too well-known to cultivators in the case of thistle, dandelion, and groundsel. Here the fruit is crowned by a circlet of feathery hairs (*pappus*), supposed to represent a specialization of the calyx. Many fruits or seeds are studded with hooks or prickles, by which they cling to the fur or wool of quadrupeds or the feathers of birds, and thus get transported to a distance. The fruits of goosegrass or cleavers (*Galium aparine*) illustrate this possibility. Succulent fruits and spurious fruits, again, are largely eaten by birds, and the seeds, being protected by firm investments, often escape digestion, and secure a chance of germinating at some distance from the parent plant.

Such arrangements as those described help to prevent plants from being smothered by the springing up of their own offspring close to them, and a small percentage of seeds reach spots where they have some chance of germinating and attaining maturity.

CHAPTER XII.

CULTIVATED PLANTS

For purposes of convenience farmers have devised a classification of crops which is well adapted to the end in view. For example, 'root crops' include turnips, swedes, mangels, and others. Grain crops, or straw crops, comprise such plants as wheat and barley, beans and peas. The only objection to this arrangement is that it may lead the beginner to make incorrect inferences. Thus, it is sometimes supposed that the manuring suited to one kind of root crop is equally suited to another—that what is good for the turnip, for example, is also good for the mangel. But this is not so, nor does it necessarily follow that it should be so.

In the botanical classification of plants the attempt is made to arrange together those plants whose structural characters most nearly resemble each other. In this way natural groups are formed, the members of each of which are believed to have sprung, in the remote past, from a common ancestor. Beans and peas are easily seen to possess a strong family likeness, and so are wheat and barley. On the other hand, there is great lack of resemblance between the bean plant and the wheat plant.

Plants which are allied to each other usually require the same kind of food. They are often liable to attack from the same kinds of insects, and to fall a prey to the same kinds of fungoid and other parasitic pests. Hence the use to the grower of learning the relationships of plants.

The method followed here is, first, to describe the crop plants individually in their botanical sequence, by discussing them in connection with the natural orders to which they severally belong, and subsequently (chapter xvi.) to deal with them from the cultivator's point of view. Advantage is taken of this arrangement to notice the commoner weeds in connection

with the cultivated plants to which they are most nearly allied. Other weed plants are referred to in chapter xiii.

CRUCIFERÆ.—The plants of this order are usually herbs (a *shrub* in the case of the wallflower), with leaves arranged alternately. The flower and fruit have already been described (pp. 167 and 176). The crucifers possess a pungent flavour, stimulating and sometimes acrid, but never poisonous; and are antiscorbutic. Notable quantities of sulphur and nitrogen are present, and these, in union with other elements, form a volatile acrid oil (such as oil of mustard). The unbearable odour which arises from a decaying heap of cabbage stumps is due in a great part to the formation of sulphuretted hydrogen and ammonia. By cultivation,

FIG. 70.—SHEPHERD'S PURSE *Capsella Bursa-Pastoris*, D.C. On the left above is the magnified fruit (a silicula).

FIG. 71.—SEED OF PENNY CRESS, *Thlaspi arvense*, L.[1]

the strong flavours of cruciferous plants have been toned down, and thereby rendered agreeable and acceptable to the palate.

Familiar crucifers are the wallflower, stock, candytuft, sweet rocket, honesty, and Aubrietia of gardens; also the woad. Amongst the weeds are shepherd's purse (fig. 70), an annual growing everywhere; the cuckoo-flower, a lilac-flowered perennial, common in moist pastures and meadows; hedge-mustard, or Jack-in-the-hedge, a white-flowered plant with heart-shaped

[1] In this and subsequent similar illustrations of seeds the *small figure* indicates the *natural size*.

leaves, frequent in hedgerows in spring, and emitting, when bruised, a powerful onion-like odour; charlock, a yellow-flowered annual, closely allied to mustard, and one of the worst weeds of arable land; the wild radish, an annual weed of cornfields; and the penny cress or Mithridate mustard (fig. 71).

The cultivated food-plants of the Cruciferæ are numerous and important. They include the turnip, cabbage, and their allies, all belonging to the genus Brassica; mustard; cress; radish; horse-radish; water-cress; and sea-kale.

Turnips, in their many varieties, are distinguished by the extent to which the root is developed into a handsome globe-like structure, often, but incorrectly, called a 'bulb' (*see* p. 152). The leaves are rough and transpire very freely. Turnips are extensively grown as food for sheep and cattle, the roots and leaves alike being eaten by stock. Turnips are likewise an important garden crop, whilst turnip-tops, as the leaves are termed, are boiled for table use.

The Swedish Turnip, or **Swede**, is the most valued of the turnip family, being both more hardy and more nutritious than the common kinds of turnips. Swedes are distinguished from other turnips by the leaves being smoother and of a bluish colour. Transpiration is much less than in ordinary turnips. But the most obvious distinction is that the swede usually has at the crown of the root a 'neck' (fig. 72), from which the leaves spring, and which is absent from the other kinds of turnips. Swedes also keep much better over the winter, and resist frost to a greater extent. The two chief groups of swedes in the market are the Green-top and the Purple-top, the varieties of the latter being most generally grown. Purple-top swedes may again be generally divided into Tankard, Intermediate, and Globe-shaped varieties. The Tankard-shaped roots, as a rule, grow well out of the ground, and their keeping qualities are supposed to be only moderate. They generally have names assigned to them which denote great size, such as Elephant, Giant, etc. The Intermediate sorts are

between the Tankard and Globe varieties in shape, and grow to a certain extent out of the ground; their keeping qualities are looked on as better than those of the Tankard. The Globe-shaped varieties are characterized by small necks, and generally grow well buried in the ground. Swedes take a leading position amongst rotation crops, but are never grown merely as a catch-crop. They usually follow the wheat crop, and take the place of the fallow or cleaning crop of the rotation,

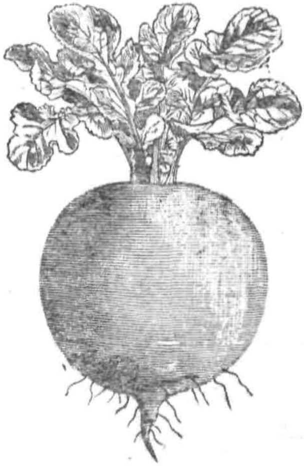


FIG. 72.—SWEDE. FIG. 73.—TURNIP.

Notice the 'neck' or 'collar' of the Swede.

most of the cleaning operations being carried out during the time the land is being prepared for sowing the swede seed.

Turnips include all varieties of these cruciferous root crops, excepting swedes. They do not possess either the hardiness or the feeding value of swedes. They are often grown as catch-crops, or may be taken in the rotation instead of swedes when it has become too late in the season to sow the latter. The existence of

numerous varieties of turnips renders it easy to make a selection suited to the time of sowing. For early feeding it is usual to grow one or more of the soft white-fleshed early varieties of poor keeping quality with purple, grey, white or green skin, such as the Purple-top Mammoth, Pomeranian White Globe, and Lincolnshire Red Globe. Some of the Hybrids are also suitable for early use if sown at the beginning of June, particularly the Centenary, All the Year Round, and the Yellow Tankard. For late autumn and winter feeding, the hardier kinds of White Turnip, such as the Imperial Green Globe and Hardy Green Round, are grown, together with the Hybrid varieties, of which the Purple-top and Green-top Aberdeens are perhaps the best known. For sowing after corn crops, such as early peas, or others which have been harvested early in August, the Stratton Green Round, the Greystone, and the Early Six Weeks are well adapted. Turnips are an exceedingly useful crop on light chalk soils, where they probably form the bulk of the root crop.

The Hybrid, or yellow-fleshed varieties, are supposed to be crosses between the turnip and swede. The leaves are like those of the turnip, but the flesh in colour, firmness and keeping qualities more resembles that of the swede in character.

Rape, Cole, or **Coleseed,** is a plant very closely allied to turnips and swedes. In fact, if neglected, these latter are liable to lose their large shapely roots, and to revert, the swede to the form of the smooth-leaved summer rape, and the turnip to that of the rough-leaved summer rape. In the case of the cultivated rape, it is the foliage and not the root which has been the object of improvement. Two kinds of rape are commonly grown, the Dwarf, or summer variety, and the Giant, or winter variety. The Dwarf is largely used on chalk soils, where it is often grown after a catch-crop. The Giant is better suited to stronger land, and it yields immense crops on rich fen soils, where it is taken as a main crop in the rotation. To a great extent the Dwarf rape takes the same place as turnips, and the Giant rape as swedes. Rape is valuable in affording

green food for forward lambs in **February** and **March**, when there is usually a scarcity of soft succulent fodder.

The **Cabbage** has been modified in so many ways by cultivators that numerous varieties have resulted. But these are all reducible to the following four groups:—

(1) The Close or Drumheaded varieties, which form a compact head by the dense overlapping of the leaves—as in the Common Cabbage, and all other hard-hearted varieties.

(2) Those of straggling open habit, due to a long upright branching stem, developing numerous leaves or sprouts, but not forming a 'heart'—as in the Thousand-headed Kale (fig. 74).

FIG. 74.—THOUSAND-HEADED KALE.

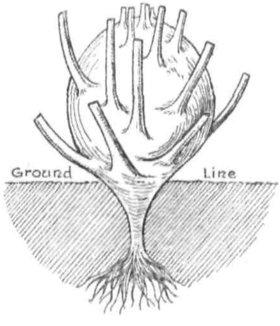


FIG. 75.—KOHL RABI. Leaf-stalks cut off short.

(3) Those in which the stem divides and forms, in the middle of the plant, a dense head of imperfect flowers—as in the Cauliflower and Broccoli.

(4) Those in which the stem is abnormally developed at the base, so as to look like the 'root' above ground, as the Kohl rabi (fig. 75), which used to be called the **Turnip-rooted Cabbage**.

In cultivation, all kinds of cabbages are better if transplanted as seedlings, their hard tough roots not being readily withered. In this respect they differ from swedes and turnips, the soft succulent roots of which would be liable to wither were transplanting attempted. Hence, where cabbages are grown, whether in farm or garden, it is desirable to have a seed-bed from which the transplanting may be effected as is found convenient.

Common or **Close-headed Cabbages** can be divided into two classes according to the shape of the head—viz., (i.) *Ox-hearts*, with oval or heart-shaped heads; and (ii.) *Drumheads*, which are of a flattened spheroidal shape. The Ox-hearts occupy less space, and can be planted closer together than the Drumheads. There are at least five well-recognized types of the common cabbage—the Imperial, the Enfield Market, the Drumhead, the Tom Thumb, and the Red or Pickling Cabbage.

Those of the Imperial type are the earliest of the field cabbages, and should be planted out, 18 in. by 24 in. apart, in autumn or early spring, so as to be fit for feeding in June and July. Those of the Enfield Market type, planted out at the same time, 2 ft. by 2 ft. apart, will be ready for feeding when the Imperials are finished. The Drumhead, or cattle cabbage, is a very heavy-cropping variety, and is usually ready for feeding between September and Christmas; it is transplanted between February and July, each plant being allowed 3 ft. by 3 ft. For late spring and summer use the plants are set out in October and November from sowings made in July and August. The Tom Thumbs are garden cabbages, grown to produce the small heads known as Collards. They often follow on the land a crop of peas or onions, harvested very early in the summer, and are planted out from 12 in. by 12 in. to 15 in. by 15 in. apart. Of Red Cabbage there are two kinds, the Ox-heart Pickler and the Drumhead Pickler, the former being the darker and the better kind for pickling. They are planted out 18 in. by 24 in. apart, and, besides their use for pickling, they are equal to

any other kind of cabbage as sheep-food. The Savoy is a very hardy cabbage, which will stand the coldest winters.

The Thousand-headed Cabbage or **Thousand-headed Kale** (fig. 74) is the variety of sprouting cabbage mostly grown on the farm. Like the common cabbage, it may be transplanted, from May to July being the best time, though generally it is found more convenient to drill it on the land where the crop is to mature. It is a heavy cropper, but the mistake is sometimes made of feeding it off too early, before the plants have had time to throw out their abundant lateral branches. The garden varieties include Cottager's Kale, Curly Kale, and Brussels Sprouts.

The **Cauliflower** and **Broccoli** are market-garden and kitchen-garden crops, and are not cultivated on the farm for stock-feeding. They are transplanted, and treated generally in the same way as other kinds of cabbage. The whitish coral-like structure in the middle of these plants consists of the over-developed inflorescence, made up of an immense number of imperfect flowers.

Kohl rabi (the name is German and signifies *cabbage-turnip*) develops above ground a large globular stem (fig. 75) upon which scars are left by the bases of fallen leaves. The green variety is almost exclusively grown, the bronze kind being but seldom cultivated. The big-topped sorts are more hardy than the short-topped forms. The latter come quickly to maturity, but are unable to face the severity of winter, and are only available for autumn feeding. The seed-beds are sown in March or April, and transplanting is effected as soon as convenient. Or, the seed may be drilled, and the young plants hoed like turnips. Kohl rabi is especially useful for soils in a dry climate where there is a difficulty in getting a good growth of swedes, or for filling in gaps in the mangel crop, and, even for this purpose alone, it is worth while having a small seed-bed in readiness upon arable farms. The tops of the hardy varieties of kohl rabi make delicious table vegetables in January.

There is a marked similarity amongst the seeds of all **plants of the turnip and cabbage kind** (genus Brassica). They possess a purplish-black colour, and a general resemblance to small shot. One reason for this similarity, notwithstanding the many external differences between the plants themselves, is that the efforts of the cultivator have not been directed to effecting modifications in the seed. His endeavour, by selection and otherwise, has been to modify the root (turnips and swedes), the stem (kohl rabi and cauliflower), or the leaf (cabbages and kale). Had the improvement of the seeds of these cruciferous plants been the object in view, it is possible that as many easily recognizable forms of seed could have been established as there are of beans, or peas, or of wheat grains. In each case, it is the part that is to be specially used as food that has been modified.

The plants of the genus Brassica are all yellow-flowered and biennial. Sometimes, in cultivation, the plants become precocious, and exhibit a tendency to shoot up their flower-stalks in the first season. This should be checked by nipping off the flower-shoot, thereby compelling the plant to restrict its energies to the production of root, or stem, or leaf, as the case may be.

Mustard is a quick-growing, yellow-flowered annual, cultivated for ploughing in green on light soils as a preparation for wheat. Where sheep are kept, it is preferable to let them consume the crop on the land, and then to plough. In Cambridgeshire and the adjoining counties the crop is grown for its seed, from which the mustard used as a condiment is obtained. Thickly sown and allowed to germinate, the green cotyledons make the salad mustard, usually eaten with the similarly grown **cress**, another agreeably flavoured crucifer. The troublesome weed **charlock**, with the blossom of which cornfields often become yellow in early summer, is sometimes called wild mustard; it is the plant most closely related to mustard.

The **radish** must be regarded as a salad plant. The roots are either *fusiform* (*i.e.*, spindle-shaped) or *napiform*

(like a turnip). In the latter case it is called the turnip-radish, and its colour is usually white or red. The radish is exclusively a garden plant.

The **horse-radish,** which is quite distinct from the radish, is a garden plant, grown for the sake of its pungent rootstock, the white flesh of which is scraped down to form an agreeable condiment with roast beef. Sometimes the roots of the poisonous monkshood have been employed by mistake instead, with fatal results.

Watercress is a white-flowered salad herb growing naturally in brooks and streams, whence it is collected in the spring and summer months for sale in towns. It is also cultivated in specially prepared shallow streams, where a sufficient supply of running water is available.

CARYOPHYLLACEÆ.—The plants of this order are herbs with opposite undivided leaves. In the flower, the four or five sepals are either joined or free, and the four or five petals are free. There are usually eight or ten stamens, and the fruit takes the form of a capsule, inside which the albuminous seeds are clustered around and upon a central peg.

This is chiefly an order of weeds, the only cultivated food plant it includes being the **spurrey.**

FIG. 76.—SEED OF CHICKWEED, *Stellaria media*, L.

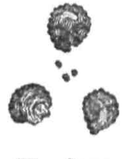


FIG. 77.—SEED OF NARROW-LEAVED MOUSE-EAR CHICKWEED, *Cerastium triviale*, Link.

Several beautiful garden flowers, as the pinks, carnations, and sweet-williams, belong to it. Amongst the weeds are the white or red campions and catch-flies of fields and hedges, ragged Robin, the stitchworts, and the sandworts. The **chickweed** (fig. 76) is a common annual surface weed of gardens and arable fields; it is a light green plant of loose straggling habit, and has an alternating line of delicate hairs along the stem. **The narrow-leaved mouse-ear chickweed (fig. 77) is**

common in pastures. The **corn-cockle** (fig. 78) is the most troublesome caryophyllaceous weed, as it grows in cornfields to about the height of the corn, with which it gets harvested. Its blackish wrinkled seeds, known as 'cockle,' are easily seen in a sample of corn, which should not be sown till cleaned of them. Corn-cockle (fig. 78) is an annual, with pale purple flowers, and is

FIG. 78.—CORN-COCKLE, *Githago segetum*, Desf.
On the left, the enlarged pistil, with five styles.

FIG. 79.—SPURREY, *Spergula arvensis*, L.
On the right, the enlarged leaf and calyx.

recognized by its woolly calyx-teeth (sepals) being longer than, and stretching beyond, the petals. The seeds of bladder campion, a white-flowered plant known by its inflated calyx, are found in samples of clover and grass seeds.

Spurrey, or corn-spurrey (fig. 79), is a white-flowered annual plant of creeping habit, with narrow fleshy leaves arranged in circlets. It grows as a weed in cornfields,

and is found naturally upon poor sandy soils. It is for such soils, upon which little else will grow, that the cultivation of spurrey, either for sheep food or silage, has been recommended. The seed is sown about April, and the crop is cut or fed when in flower. The seed usually found in the south of England has a papillose or dotted surface; fig. 80 shows the rarer form of seed in the northern counties.

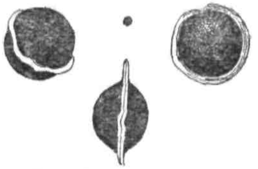


FIG. 80.—SEED OF SPURREY, *Spergula arvensis*, L.

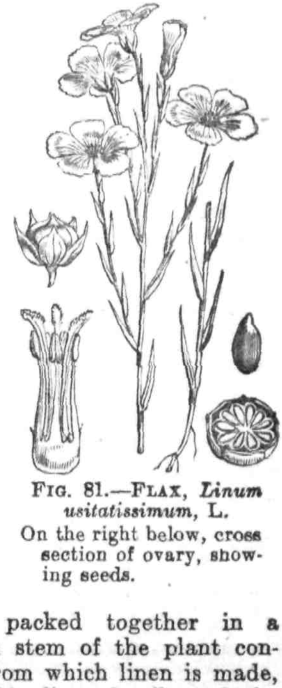


FIG. 81.—FLAX, *Linum usitatissimum*, L. On the right below, cross section of ovary, showing seeds.

LINACEÆ is a small order, interesting as including the **flax** plant (fig. 81). This is a slender annual herb, growing from one to two feet high, possessing narrow alternate leaves and deep blue flowers, the petals which expand in the morning falling off in the evening. A field of flax in bloom is a beautiful sight. The flattened albuminous seeds (linseed) are closely packed together in a spherical capsule. The tough stem of the plant contains the valuable flax fibre from which linen is made, whilst the crushed seed yields linseed oil, and the residue is compressed into oil-cake (linseed cake), used for feeding cattle. The boiled seed added to a mixture of chopped roots and chaff, is also often employed for feeding cattle in winter. Flax is but little grown in England; it is much more largely cultivated in Ulster.

In 1913 there were only 648 acres of flax in the whole of Great Britain. *If this plant is not known to the student, a few of the seeds should be sown in the garden in April. It is better to soak the linseed in water for twenty-four hours before sowing, and to wash away the mucilage which oozes out.* The **purging flax** (*Linum catharticum*, L.) a slender annual white-flowered plant, with a much-branched stem, is a weed of poor land.

LEGUMINOSÆ.—The plants of this order are either herbs (clover, vetches, etc.), shrubs (furze, broom, etc.), or trees (the introduced laburnum, acacia, etc.). The leaves are usually compound—*i.e.*, broken up into distinct leaflets. The flowers are very characteristic, and, whether large, as in the pea (fig. 67), or small, as in a clover head, they are all built up on the type which has already been fully described (p. 168) in the case of the bean. The papilionaceous flowers, and the pod (or *legume*) which forms the fruit, sufficiently distinguish the British members of the order. The food products of this order are specially rich in nitrogenous ingredients. Those Leguminosæ which yield food-grains (peas, beans, lentils) are called **pulses.** This name is sometimes extended to all plants of the order used for food, so that pulse crops are leguminous crops.

Peas are cultivated both as farm and as garden crops. In the former case they are allowed to ripen, when the seeds are threshed out, and the dry straw or 'haulm' is used as fodder. In the latter case the unripe seeds (green peas) are gathered for a table vegetable. Near large towns, peas are stripped on the farm, and the green haulm is either employed as fodder, or made into silage. Peas have weak straggling stems furnished with tendrils, by the twining habits of which the plants are pulled up into the light and air, and in garden cultivation sticks are planted along the row to afford them support. In field cultivation, however, sticks are not used, and the plants spread amongst each other in the same way as vetches. They are a somewhat uncertain crop.

Most varieties of garden pea have a white blossom; while field peas have bluish-purple flowers. Common

field varieties are the Maple, the Early Maple, the Partridge, the Early Dun, and the Common Grey. Prussian Blues and many varieties of white peas, originally introduced as garden peas, have found their way into field culture. Amongst the soft or wrinkled peas grown as vegetables are the British Queen, Fortyfold, Ne Plus Ultra, Telegraph, and Yorkshire Hero.

Peas are a crop suited to light land, and, when grown in a rotation, they follow barley, and thus give the land a rest from clover.

Beans are grown as a field crop, yielding the familiar Horse Bean; also, as a garden crop, the Broad Bean or Windsor Bean. Horse beans include the large ticks or negro beans, the small ticks, and the common variety. Beans are more hardy than peas, and have a stiff upright mode of growth. They are also a more certain crop than peas, but require a stronger, deeper soil. The more hardy kinds, sown in the autumn, are called winter beans; the more delicate varieties, sown in February, are called spring beans. Field beans are drilled or dibbled in rows, 18 to 24 inches apart. Under favourable conditions they produce pods almost down to the ground, as a result of the free admission of light and air. By the time the crop is ready to be harvested for its seed, the haulms are well-nigh black, so that beans are a **black straw crop.** Bean straw is used for feeding, and is often mixed with pea-haulm for the purpose.

Broad beans are grown in the garden for the sake of their unripe seeds, which, like green peas, are boiled for table use.

The Scarlet Runner Bean (Kidney bean) is a garden plant, with a long twining stem and bold scarlet flowers. It is a native of Mexico, and is cultivated in English gardens as an annual for the sake of its unripe pods, which are sliced and cooked for table use. The part that is eaten is, of course, the immature ovary containing the unripe seeds.

The dwarf French beans are varieties of the kidney bean. The Haricot bean, largely used as food in France and Italy, and to some extent in England, is another variety.

Clovers are members of the genus Trifolium. Their leaves are made up of three leaflets (whence the name *trifolium*). Notice, in a clover field, how the leaves of the plants close up at sunset, thereby offering the smallest surface possible to the cooling effects of radiation during night; this is an example of what Darwin called the *sleep of plants*. The numerous small papilionaceous flowers are aggregated in dense heads. Clovers are not cultivated as food for man, but are amongst the most common of the farm crops grown either for green forage or for hay.

The clovers usually found in cultivation are named in the following table:—

Botanical Name.	Common Name.	Colour of Flower-head.
Trifolium repens	White or Dutch clover	White.
Trifolium pratense... ...	Broad clover	Red or purple.
Trifolium pratense perenne	Cow-grass	Do.
Trifolium hybridum ...	Alsike	Pink and white
Trifolium incarnatum ...	'Trifolium'	Crimson.
Trifolium minus	Yellow suckling clover	Yellow.

White clover, Dutch clover, or honeysuckle clover, *Trifolium repens* (fig. 82), receives its specific name of *repens* in allusion to its creeping habit, numerous prostrate stems or stolons being given out at the crown, and helping to spread the plant in all directions. The fruit is a flat pod, containing three or four seeds (fig. 83) of a sulphur or orange colour. It is a well-established perennial plant found in old feeding pastures of prime quality, in which it helps to form a rich turf of close bottom-herbage. If sown by itself it is usually folded with sheep, as its habit does not permit of its being profitably cut with the scythe. But sheep should, for the first few days, only be allowed on the crop when their appetite is partly satisfied, otherwise they eat so much that they become *hoven* or blown, through the accumulation of gas in the stomach. A luxurious growth of white clover often follows a dressing of lime or

phosphates on poor grass land, especially on soils naturally deficient in these ingredients. This, no doubt, is due to the weak clover plants, already existing in the pasture, being stimulated directly or indirectly by the dressing applied.

Red or broad clover, *Trifolium pratense* (fig. 84), is also known as purple or meadow clover. It has a fine head of purple flowers, is a very robust plant with a slightly downy surface, and its leaflets bear a whitish horseshoe-shaped or triangular mark.

The fruit is a one-seeded pod, so different from the ordinary pods of the Leguminosæ that it must be specially examined. It does not open lengthwise, but is divided into an upper and a lower half. The upper is a smooth shining cap, and the lower is a small thin-walled box, by the tearing of which the seed is set free. Some of these curious pods are often present in samples of red clover seed, though, as they are easily separated, they ought not to be. The seed (fig. 85), viewed in bulk, is bright and shining, and has a purplish tinge. A good seed is of a dark purple colour at one end, gradually shading down to a light yellow.

FIG. 82.—WHITE CLOVER, *Trifolium repens*, L.

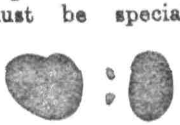


FIG. 83.—SEED OF WHITE CLOVER.

Red clover is commonly grown as a hay crop, but it is also folded with sheep. On good soils it will stand two or more years. This is the clover which is specially

susceptible to 'sickness,' a disease associated with the presence of minute eel-worms in the stem of the plant. As 'clover sick' land usually requires some years in order to sufficiently recover to carry clover again, it is not advisable to grow it—certainly on light open soils —more than once every ten or twelve years. A healthy crop of red clover generally affords a most abundant yield. [Clover-sickness is sometimes due to a fungus.]

Cow grass (*Trifolium pratense perenne*) is not a true grass, but is a variety of the red clover, which, though slower in arriving at maturity, is possessed of a more lasting character, and is usually less liable to clover sickness. It is, therefore, well adapted for use in a mixture of seeds intended to remain down for some time. Being later than the red clover, it usefully supplements the latter, as it comes in season after the red clover has been cut once, and before it is ready to fold or to cut again. But, as it is cut late, cow grass yields only a moderate aftermath. Cow grass is thus an example of a 'single-cut' clover, whereas the other variety is a 'double-cut' clover. It is not possible to distinguish the seed of common red clover from that of cow grass.

FIG. 84.—RED CLOVER, *Trifolium pratense*, L.

FIG. 85.—SEED OF RED CLOVER.

Alsike clover (*Trifolium hybridum*) is a smooth perennial plant with hollow stems. Its whitish and pinkish flowers are arranged in loose heads on long stalks, the plant thus presenting an appearance intermediate between that of white clover and that of broad clover. The pod is short and contains from one to three small dark green seeds (fig. 86). Alsike grows freely on most soils, and will thrive on wet land unsuited to the older varieties; it is particularly free from clover sickness, so that when occasion arises it forms a very useful substitute for broad clover.

Crimson clover — scarlet, carnation, or Italian clover —*Trifolium incarnatum* (fig. 87), is the plant which farmers call '**trifolium.**' It is characterized by its elongated velvety head of dark crimson flowers. There are three forms generally grown in this country—the Early Red Trifolium, the Late Red, and the Extra Late Red—in addition to which there is a white-flowered variety, *T. album*. It is essentially a single-cut clover, and is commonly grown as a catch-crop, the seed being merely harrowed in upon a cereal stubble directly the corn crop is off the ground. The trifolium is fit for feeding in May and June, and after it has been folded by sheep it may be broken up to be followed by root crops.

FIG. 86.—SEED OF ALSIKE.

FIG. 87.—'TRIFOLIUM,' *Trifolium incarnatum*, L. With enlarged floret.

Yellow suckling clover, or lesser yellow trefoil, *Trifolium minus* (fig. 88), is a small annual yellow-flowered species, of much less size than the clovers that have already been described. It is a smooth plant, with slender flower-stalks. It is often grown in association with rye-grass, and begins to shed its seed freely after midsummer, especially in hot dry seasons.

The **hop trefoil** (*Trifolium procumbens*) has a rather prominent head of primrose-coloured flowers. In each corolla, the vexillum (fig. 67) is bent back somewhat, giving the whole head the appearance of a small yellow hop-cone. It grows chiefly on limestone soils, and is not cultivated. The **zigzag trefoil**, *Trifolium medium* (fig. 89), with a head of rose-purple flowers, and a straggling zigzag stem, takes possession of the soil with great rapidity.

FIG. 88.—YELLOW SUCKLING CLOVER, *Trifolium minus*, Sm.
With enlarged floret and fruit.

FIG. 89.—SEED OF ZIGZAG TREFOIL, *Trifolium medium*, L.

The true clovers belong exclusively to the genus Trifolium. An allied genus, Medicago, contains several species which are popularly regarded as clovers, though they are not really so. In Medicago, as in Trifolium, each leaf is broken up into three leaflets. But the flowers of Medicago are arranged in compact *racemes*, a number of short-stalked florets springing from a common axis, so that the result is not unlike a clover-head. Again, the pod of Medicago is usually either curved or spiral, whilst in Trifolium it is nearly straight. Two species of **Medicago** are of agricultural interest.

Trefoil or yellow clover, *Medicago lupulina* (fig. 90), also known as black medick or nonsuch, and called 'hop' by farmers, has some resemblance to *Trifolium minus*. But the whole plant is hairy or downy, the florets forming the head are numerous and very bright yellow, and the curved pod (fig. 90) becomes black as it ripens, none of which characters are true of *Trifolium minus*. Moreover, in trefoil the corolla falls away after flowering, and the black roughish kidney-shaped pod is exposed to view, whereas in the yellow suckling clover the brown withered remains of the corolla embrace the pod. The seed of trefoil has a yellowish-brown, shining appearance; each pod contains one seed. Trefoil does not possess the high feeding properties of the true clovers. When cultivated, it is usually in a mixture of seeds intended to remain down for a short period only. It is thus grown, especially on light chalk soils, in association with rye-grass.

FIG. 90.—TREFOIL, *Medicago lupulina*, L.
On the left the black curved pod enlarged; on the right an enlarged floret.

Lucerne, *Medicago sativa* (fig. 91), is a plant which at first appears to be very distinct from the trefoil just described. But an examination of the characters of their flowers and fruits shows their close relationship. Lucerne, however, is a taller, more robust plant, with loose racemes of bluish-purple flowers. The fruit (fig. 92) is a spiral pod, turned on itself two or three times, and containing a number of kidney-shaped seeds. Being a very deep-rooted plant, lucerne is well qualified to thrive in dry soils and during droughty seasons. It is best sown by drilling, or by transplanting, as if sown broadcast it is impossible to get between the plants to clean the land. The crop will stand for a number of years, and is

used chiefly for green soiling (*see* p. 263), though in some districts it is made into hay. It affords excellent fodder for horses.

Two other leguminous plants largely grown are sainfoin and vetches. Sainfoin is cultivated as a main crop, but this is hardly the case with vetches, though they are sometimes taken as a main crop on heavy land.

FIG. 91.—LUCERNE, *Medicago sativa*, L.

FIG. 92.—TWISTED OR SPIRAL POD (LEGUME) OF LUCERNE.

Sainfoin, *Onobrychis sativa* (fig. 93), is a robust plant, with a stout woody root, a long handsome leaf of 12 to 20 leaflets, and bold elegant racemes of large pink flowers. There are few prettier sights on the farm than a field of sainfoin, such as can be seen in chalk districts, in full bloom. The fruit is a large wrinkled pod, containing a single kidney-shaped seed of chocolate-brown colour. Sainfoin is allowed to remain down for from three to seven years, and is either grazed by stock or mown for hay. But, if folded too soon, sheep bite the heart out of the plant, and the crop is seriously injured.

There are two cultivated varieties of sainfoin—(1) The Common or English Sainfoin, which gives only one cut of hay in the year, and is of a more perennial character than the other, lasting some five years or

more under suitable circumstances; and (2) The Giant or French Sainfoin, which is more luxurious in its growth at first, and gives two cuts of hay per annum. This variety, however, is short-lived, not lasting more than two seasons.

Vetches or tares, *Vicia sativa* (fig. 94), have the terminal leaflets of the compound leaves converted into tendrils. The stem is trailing, and the pale purple

FIG. 93.—SAINFOIN, *Onobrychis sativa*, L.

FIG. 94.—VETCH OR TARE, *Vicia sativa*, L. With leaflet, flower, and pod on larger scale.

flowers arise, one or two together and without stalks, from the leaf axils. The straight hairy pods are not unlike those of the sweet pea, but smaller, and they contains from four to six seeds. The plant is an annual and there are two varieties, known as winter vetches and spring vetches, the former being sown in September, and the latter in February, March, or April. The crop should not be cut till the pods have formed, though long before they ripen. Both varieties are highly nutri-

Lupines (*species of Lupinus*) are better known in England as cottage garden flowers than as forage crops. The narrow leaflets all radiate from a common point, and the inflorescence is a stately raceme of blue, yellow, pink, or white flowers. They are not natives of this country.

Furze, gorse, or **whin** (*Ulex europæus*) is a prickly shrub, with deep yellow blossoms of somewhat sickly odour. It is raised from seed, on waste land not capable of being otherwise utilized. Horses, cattle, and sheep readily eat the nutritious young shoots, as also the older parts after they have been bruised, so as to crush the prickles. It provides winter as well as summer food.

Serradella (*Ornithopus sativa*) is cultivated as a forage crop on the Continent; and **fenugreek** (*Trigonella*) is grown for its seeds, which are used as a condiment.

FIG. 98.—BURNET, *Sanguisorba officinalis*, L. With enlarged florets.

Other native leguminous plants, not cultivated, are the broom, rest-harrow, and meadow vetchling, the last-named being a yellow-flowered plant growing naturally in hayfields.

ROSACEÆ is a natural order that furnishes no farm crops, but includes a considerable number of the most useful plants of the garden and orchard. The botanical characters of the order are extremely varied. It embraces herbs (burnet [fig. 98], silverweed, strawberry), shrubs (raspberry, bramble), and trees (plum, apple). To understand the distinctive characters of the flowers in this order, blossoms of the hawthorn, dog-rose, and blackberry should be examined. The flowers are *perigynous* (p. 170), the five free sepals, five free petals, and

numerous stamens springing from the edge of the cup-shaped receptacle. In the weeds called burnet (fig. 98) and lady's mantle there are no petals. The carpels range from one to five or more, and the fruits are of very various kinds, but they are never legumes—the characteristic fruit of the Leguminosæ.

In many rosaceous plants the fruit is a drupe (*see* p. 176), of which the **cherry** is an example. All kinds of **plums** (including the wild **sloe** or **blackthorn**), **damsons, greengages, cherries, apricots, peaches, nectarines,** and **almonds** belong to this type, and so do the common laurel and Portugal laurel of shrubberies, but not the bay laurel.

In the **raspberry, blackberry, dewberry,** and other forms of **bramble,** the fruit is made up of a collection of small drupes or drupels.

In the **strawberry** the 'fruit' is false or spurious (*see* p. 177).

The calyx is *persistent* in the case of the raspberry, blackberry, dewberry, and strawberry. It can always be found beneath these 'fruits.' There is often what appears to be a second calyx—*epicalyx*—outside the ordinary one. This is in reality a circlet of bracts.

One other type of rosaceous fruit of industrial value (the **pome**) is that met with in the **apple** and **pear,** in their scores of varieties. They are spurious fruits (*see* p. 177).

Other native rosaceous plants, not previously mentioned, are the wild rose, meadow-sweet, cinquefoil, agrimony, and cotoneaster.

RIBESIACEÆ is a small order to which the **gooseberry** and the **red** and **black currant** belong. These shrubs are known as 'bush fruit,' and the fruit they produce is, in each case, a true berry. The flowers are **epigynous** —*i.e.*, the cup-shaped receptacle is fused with the ovary, so that the sepals, petals, and stamens, springing from its edge, *appear* to grow from the top of that organ. The ovary matures rapidly into the fruit, the 'eye' of which consists of withered sepals, petals, and stamens. Gooseberries and currants are largely used both as fresh fruit for table use, and also for preserving.

CUCURBITACEÆ.—Britain possesses only one native plant of this order—the **white bryony** (*Bryonia dioica*), a tendril-bearing plant which climbs the hedgerows and produces conspicuous bunches of soft red or yellowish berries, which are poisonous. The greenish-white flowers are unisexual, the male and female flowers being each confined to separate plants. Examine some specimens in June or July, and notice especially the curved anther-lobes of the stamens in the male flowers. Observe, also, the elaborate clasping and coiling of the tendrils, whereby the feeble stem of the plant is lifted up so that the leaves and flowers get their full requirement of air and light.

The cultivated plants of the order include **cucumbers, vegetable marrows, pumpkins, melons, water melons, gourds,** etc. These are all grown for the sake of their fruits, which are large watery berries possessing special flavours. Some of them (the melons) are consumed as fruits, others (vegetable marrows) are cooked as vegetables, some (cucumbers) are used as salads, whilst a small variety of the cucumber (the **gherkin**) is pickled. Pumpkins are the largest fruits known, and even in this country have been grown to a size exceeding 6 feet in circumference, and to a weight of over 200 lb.

Pumpkins and melons, and sometimes cucumbers, are grown under glass, upon rich warm beds specially prepared. They are raised from seed, which is obtained by washing the pulp away from the fruit; and they may easily be multiplied by cuttings. When grown in frames they have to be specially fertilized (*see* p. 173).

Vegetable marrows and also cucumbers are grown out in the open air, and the latter are largely cultivated as a market garden crop, the smaller fruits (gherkins) being reserved for pickling. The seeds are large, flattened, and exalbuminous.

UMBELLIFERÆ is the name of an order in which the inflorescence is made up of a number of stalked flowers, springing in all directions from a point at the end of the floral axis. Such an inflorescence is called an **umbel.** If each branch of the umbel branches again similarly, a collection of little umbels results, and the whole is

called a *compound umbel* (fig. 99). The main branches spring from within a circlet (involucre) of bracts, and there are similar but smaller circlets (involucels) surrounding the base of each component umbel. The Umbelliferæ are herbaceous plants, with hollow furrowed stems, well-developed leaves, usually much divided, and sheathing bases to the leaf-stalks. They are mostly white-flowered, but some are yellow. The flowers are epigynous, and the flower-leaves in *fives*, except the carpels, which are two in number and fused together. Many plants of the order are possessed of strong odours, and certain species are poisonous. The cultivated umbellifers include the carrot, parsnip, celery, parsley, fennel, caraway, and coriander.

FIG. 99.—DIAGRAM OF A COMPOUND UMBEL.

The **carrot** (*Daucus Carota*), as it grows wild in the fields, is in some districts called bird's nest, because its compound umbel of white flowers—often with a purple flower in the centre—has the concave form of a nest. Pull up one of these plants, notice the long tap-root, and break it through so as to observe its odour. The cultivated carrot, with its handsome well-developed tap-root, has been obtained by cultivation and selection from this wild progenitor. The varieties generally grown for field cultivation are the Belgian White, the Red Intermediate, and the Yellow Intermediate. Carrots afford a highly nutritious food, and all kinds of farm stock —horses in particular—are partial to them. The 'seed' of this, as well as of the other umbelliferous crops, is really the dry fruit (called a *cremocarp*, consisting of two one-seeded halves—*mericarps*). Carrot 'seeds' are covered with a coarse hairy outgrowth which causes them to adhere together; hence, before sowing, they should be well rubbed between the hands with dry ashes, bran, or powdered charcoal.

The juice of the red carrot is sometimes used in the dairy to give a colour to cheese and butter.

The **parsnip** (*Pastinaca sativa*) has not been much used as a cattle food in England, and is chiefly grown as a garden crop. It is an improved form of the wild parsnip, which is a common weed of poor grass land and waste places, with a root possessing the characteristic odour of the cultivated plant. The umbel is made up of yellow flowers. As a rule, the roots of the parsnip are less shapely than those of the carrot. Being a very hardy plant, the parsnip may be left in the ground through the winter. The 'seed' of the parsnip consists of the half-fruits (*mericarps*).

Celery is the cultivated form of a wild plant (*Apium graveolens*), with umbels of greenish-white flowers, found growing in salt marshes. The seedlings are transplanted into deep trenches, which are gradually filled up with earth as the plants increase in height. The access of light to the succulent leaf-stalks being thus prevented the green pigment chlorophyll does not develop, and the leaf-stalks acquire that blanched or white appearance with which they come to the table. In its wild condition it is somewhat poisonous, but in the process of blanching the leaf-stalks lose the poisonous property, or rather it is not developed.

Parsley is another modification of a plant found wild in England (*Carum Petroselinum*). The garden parsley is a savoury herb, the part employed being the leaves, which are also used for garnishing.

Sheep's parsley is a field variety, the 'seed' of which is sometimes included in mixtures for laying land down for sheep-grazing. It is occasionally sown on sheep runs, the animals being fond of it.

Fennel is a garden derivative of the wild fennel (*Fœniculum vulgare*) of sea cliffs. It is a perennial, with very finely divided drooping leaves, and umbels of yellow flowers. The leaves have a strong aromatic odour, and are used in making fish sauces, and for garnishing.

Caraway, *Carum Carvi* (fig. 100), is a white-flowered

native plant, sparingly cultivated for its 'seeds' (half-fruits—*mericarps*), which are used for flavouring bread, confectionery, and spirits. The plant is easily raised by sowing a few caraway seeds. **Coriander** (*Coriandrum sativum*) is a somewhat similar plant, the 'seeds' of which are used in the same way.

FIG. 100.—CARAWAY, *Carum Carvi*, L.
With enlarged flower and fruit, and section of latter.

Excepting the fennel, all the foregoing plants are biennials, and require two seasons in order to bring their seed to perfection.

Of the weed umbellifers, the commonest are the **hedge parsleys** (*Torilis nodosus* and *T. Anthriscus*), which are mostly annuals. They are at once recognized in the hedgerows and on the waysides by their characteristic leaves, and umbels of white or pink flowers, which appear from May to July or August. These plants are sometimes gathered for feeding rabbits. The **cow-parsnip**, or **hog-weed** (*Heracleum Sphondylium*) is a tall coarse plant, growing from five to ten feet high, with rough leaves and a conspicuous white umbel. The **shepherd's needle**, or **Venus's comb** (*Scandix Pecten-Veneris*) is an abundant weed in cornfields. It is a white-flowered annual, and derives its name from the fact that its clusters of fruits (*cremocarps*) lengthen out to a remarkable extent after the plants have flowered. The **earth-nut**, or **pig-nut** (*Conopodium denudatum*, fig. 101), is a perennial weed of pastures. Its leaves are much divided into linear segments, and its flowers are white. It has blackish tuberous roots, about the size of a chestnut, which are edible, and possess a sweetish taste;

'underground nuts' and 'earth chestnuts' are other names locally applied to them.

Poisonous Umbellifers.—Certain umbelliferous weeds are highly poisonous. Amongst these the hemlock and fool's parsley are land plants; the water dropwort, water parsnip and cowbane are water plants. The **hemlock,** *Conium maculatum* (fig. 102), which grows in waste places, attains a height of from two to four feet. It is white-

FIG. 101.—EARTH-NUT, *Conopodium denudatum*, Koch. With enlarged flower and fruit, and section of latter.

FIG. 102.—HEMLOCK, *Conium maculatum*, L. With enlarged flower and fruit, and section of latter.

flowered, and has a smooth polished stem, bearing brownish red blotches. On being bruised the plant emits an odour like that of mice. The whole plant is poisonous, and the seeds are especially so. **Fool's parsley,** *Æthusa Cynapium* (fig. 103), is a white-flowered annual, also growing in waste places, and occasionally in kitchen gardens. It reaches a height of two feet, and may be recognized by the three narrow leaves (bracts)

which grow downwards from one side of the base of each little umbel of the compound umbel. It sometimes grows amongst parsley, from which it is distinguished by the bluish tint of its leaves. It is doubtful whether this plant is really poisonous, and whether it has not sometimes been blamed instead of hemlock.

Water parsnip has some resemblance, both in the shape of the leaf and in odour, to the cultivated parsnip. It is a white-flowered perennial growing in ditches and streams. Its leaves sometimes get gathered with watercress, from which they are easily distinguishable both by their appearance and their flavour. There are two species, a broad-leaved and a narrow-leaved (*Sium latifolium* and *S. angustifolium*). **Water dropwort** (*Œnanthe fistulosa*) grows in marshes and on the banks of rivers and ditches, where it attains a height of from two to five feet. It is white-flowered, and the submerged leaves are very much divided. It is sometimes mistaken for celery. The **cowbane** (*Cicuta virosa*) has an erect, much branched, furrowed stem, and grows to a height of three to four feet in ditches. Cattle have been poisoned by eating its leaves. The umbels are four or five inches broad, but the flowers are very small. Cowbane, fortunately, is not of common occurrence.

FIG. 103.—FOOL'S PARSLEY, *Æthusa Cynapium*, L. With enlarged flower and fruit, and section of latter.

COMPOSITÆ is the name given to a very extensive natural order of plants, the members of which are characterized by their inflorescence. Imagine, in such an inflorescence as the simple umbel (p. 204), that the individual flowers are all deprived of their stalks. The result would be a number of stalkless (or *sessile*) flowers

all crowded together. Such a structure is called a *composite* or *capitate* inflorescence, or, briefly, a **capitulum or head,** and it is met with in all plants belonging to the Compositæ. A daisy head or dandelion head is, therefore, not a flower, but a collection of flowers—an inflorescence. Examine a daisy head. In the middle (the *disk*) are seen a number of yellow florets, which are called *tubular* florets. Around the rim (the *ray*) are many white florets, with the corollas developed to one side; these are called *ligulate* florets. Such florets may be still better seen by breaking open the head of a sunflower, from which florets of each kind may be taken for closer examination. Many composite plants have both tubular and ligulate florets in the head—as daisy, ox-eye, marigold, sunflower; others have the head composed entirely of ligulate florets—as lettuce, chicory, hawkweed, sowthistle; in some, again, the florets are all tubular—as tansy, wormwood. The overlapping greenish leaves surrounding the head of a composite inflorescence are *bracts*, collectively forming an involucre. Do not mistake them for sepals. The chamomiles, used for making chamomile tea, are the dried inflorescences of a native composite plant.

Many of the Compositæ possess a milky juice, containing bitter and other principles. By cultivation these are sufficiently modified to be made acceptable to the palate, especially when presented in the form of green salad herbs. Yet, considering the immense number of species included in the order, singularly few are cultivated. The only species grown on the farm are yarrow and chicory, to which may be added the lettuce and dandelion of the garden.

Yarrow or milfoil, *Achillea Millefolium* (fig 104), is a plant of common occurrence in pastures and meadows, and on roadsides. Its leaves are very much divided, and its inflorescence, usually white, occasionally becomes pink or reddish. Sheep eat yarrow in moderate quantities, perhaps as a condiment or a medicine. As is the case with all the Compositæ, the 'seed' used for sowing is really the fruit. Yarrow is included in mixtures of seeds for laying down light soils to grass, and

its roots aid in binding loose soils together It is a perennial, and grows to a height of about one foot.

Chicory or **succory**, *Cichorium Intybus* (fig. 105), is a native perennial, growing to a height of three feet or more, and bearing heads of handsome blue flowers, which are given off the stem in pairs. It has been cultivated on a moderate scale as a cattle food, the foliage being used for this purpose. The root, dried and ground, forms the chicory sold by grocers, and often

FIG. 104.—YARROW OR MILFOIL, *Achillea Millefolium*, L.

FIG. 105.—CHICORY OR SUCCORY, *Cichorium Intybus*, L.

mixed with coffee. Its young blanched leaves are used as a salad, as are also those of the closely related **endive.**

Lettuce (*Lactuca sativa*) is the commonest of all salad plants grown in English gardens. The varieties of this agreeable plant are very numerous, differing in size, texture, colour, and period when in season. Lettuce is a yellow-flowered biennial, and ripens its 'seed' the

year after it is sown, though precocious plants are liable to run to top in the same season, unless the flowering shoots are nipped off.

The **dandelion** (*Taraxacum officinale*) makes an excellent addition to a salad, and there is no reason why this plant should not be as largely cultivated for this purpose in England as it is in France, where it is also sent to the table cooked.

The **sunflower** (*Helianthus annuus*) is a stout upright annual, bearing large terminal heads of flowers. It is cultivated for its seeds—really the fruits—which have a high feeding value.

The **Jerusalem artichoke** (*Helianthus tuberosus*) is closely allied to the sunflower, which it much resembles in general habit, but the solitary terminal yellow flower heads are smaller. It is a perennial plant, somewhat difficult to get rid of when it has once taken possession of the soil. It is grown for the sake of its tubers, which were formerly used for many purposes to which the potato is now generally applied. It is both hardy and productive, and is grown from sets like the potato.

The **artichoke** (*Cynara Scolymus*), though a composite, is quite a distinct plant from the foregoing. Its large gashed leaves, two or three feet long, and of a grey colour, are very noticeable. A stout stem, three or four feet high, carries flower-heads, at the base of which are numerous thick overlapping scaly leaves (bracts).

Many compositaceous weeds are furnished with stout perennial rootstocks, which are difficult to extirpate. On meadow land the only safe measure to adopt is to pull them up bodily. But both annual and perennial Compositæ are, in the case of many species, furnished with an easy means of dissemination of the 'seed.' The florets are so crowded together that the calyx is often reduced to a mere ring of hairs, termed a **pappus** (*see* p. 177), surmounting the fruit, and as the fruit ripens the petals and stamens wither away. Although this structure is not present in all Compositæ—not in the daisy, for example—it is obvious that those compositaceous weeds which possess it have a ready means of spreading themselves over the land. Hence,

any measures directed to getting rid of such weeds must be put in operation before the flower heads have 'gone to seed.'

Amongst the commonest composite weeds are various species of **hawkbit** (*Leontodon*) and **hawkweed** (*Hieracium*), all of which are yellow-flowered perennials. Other yellow-flowered species are **sow-thistles** (species of *Sonchus*) and **groundsel** (*Senecio vulgaris*), some of which are annuals and others perennials. The **corn-marigold** (*Chrysanthemum segetum*) is a handsome yellow-flowered annual weed of cornfields, whilst the closely allied yellow and white **ox-eye Marguerite**, *C. Leucanthemum* (fig. 106), of meadow land is a perennial, as is also the **daisy** (*Bellis perennis*), with its troublesome rosette of leaves lying close to the ground and usurping the place of useful pasture plants. The **scentless Mayweed** (*Matricaria inodora*) is a white-flowered annual common in cornfields, as is the **stinking chamomile** (*Anthemis Cotula*).

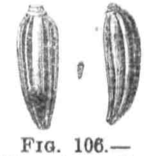


FIG. 106.—'SEED' OF OX-EYE DAISY, *Chrysanthemum Leucanthemum*, L.

Purple-flowered composite weeds include the various prickly **thistles** (*Carduus*, *Onopordon*, and *Carlina*), which are either biennials or perennials, and the perennial **knapweed** (*Centaurea nigra*), with its hard blackish head conspicuous before flowering. Another knapweed, the beautiful **blue-bottle** or **cornflower** (*C. Cyanus*), is an annual weed in cornfields. The **burdock** (*Arctium Lappa*), a coarse purple-flowered biennial growing in waste places, is the largest-leaved British plant, and is often—but quite incorrectly—called wild rhubarb. The burs, which catch in the clothing and in sheep's fleeces, are formed by hooked points upon the bracts of the flower heads.

SOLANACEÆ.—The most familiar example of this order is the potato, the flower of which should be examined. The five sepals are all joined together, as are the five petals; while the five stamens, with their very conspicuous orange-coloured anthers, arise from the short corolla tube. The two carpels join together to form a

two-chambered ovary, as may be seen by cutting it across transversely, and the fruit is called the potato 'apple' or potato 'berry.'

The **potato** (*Solanum tuberosum*) is cultivated for the sake of its underground stem, or tuber (*see* p. 151). In Jersey and Guernsey it is extensively grown under glass, in order to secure the early market when prices are high. For ordinary purposes of cultivation the crop is grown from tubers, which may be cut up into 'sets' before planting. New varieties are obtained by sowing the true seed, but it takes several years to establish a fresh strain. The introduction of these new forms is necessary, inasmuch as each variety appears in time to decline in value, becoming less prolific and reliable. It is obvious that it is only by the cross-fertilization rendered possible in the flower that new strains can be originated; no cross-breeding can be practised when propagation is continued year after year by means of the tubers only.

British Solanaceæ comprise the foul-smelling **henbane** (*Hyoscyamus niger*), the **woody nightshade** or **bittersweet** (*Solanum Dulcamara*), and the **deadly nightshade** (*Atropa Belladonna*). These plants all possess poisonous principles, and are, therefore, dangerous, as are also the leaves and fruit of the potato. Consequently potato haulm is burned, and is never used as food.

Other poisonous or highly narcotic plants of the order are **tobacco** (*Nicotiana Tabacum*) and **thorn-apple** (*Datura Stramonium*). The red capsicums and the smaller red chillies, seen in pickle-jars, are fruits of this order. The dried capsicums, when ground, yield Cayenne pepper.

The **tomato** (*Solanum Lycopersicum*), or love apple, is cultivated for its fruit, a handsome red or yellow berry, which is used either as a salad, a culinary vegetable, or as a constituent of sauces. In England it thrives best when trained against walls, but since it cannot be relied upon to ripen its fruit out of doors, it is extensively grown under glass, and, being an annual, it is raised from seed. It is a weak, trailing plant, with soft stem, winged leaves, and yellow flowers. Observe the odour of its foliage, almost as powerful as that of henbane—a weed of waste places.

The **egg-plant** or **aubergine** (*S. esculentum*) is another introduced member of the order, cultivated for its egg-shaped fruit.

LABIATÆ is an order of greater interest to gardeners than to farmers. To it belong many of the sweet-smelling and savoury herbs, such as **sage** (*Salvia officinalis*), **mint** (*Mentha viridis*), **thyme** (*Thymus vulgaris*), **marjoram** (*Origanum onites*), **balm** (*Melissa officinalis*), **horehound** (*Marrubium vulgare*), **lavender** (*Lavandula vera*), and **rosemary** (*Rosmarinus officinalis*). It also includes such weeds as **white deadnettle** (*Lamium album*), **red deadnettle** (*L. purpureum*), **hemp nettle** (*Galeopsis Tetrahit*), **bugle** (*Ajuga reptans*), and **self-heal** (*Prunella vulgaris*—fig. 107). The plants of the order are recognized by their square stems, opposite leaves, two-lipped corollas, four

FIG. 107.—SEED OF SELF-HEAL, *Prunella vulgaris*, L.

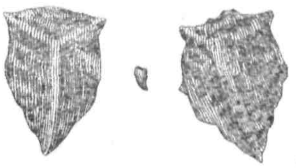


FIG. 108.—SEED OF VIPER'S BUGLOSS, *Echium vulgare*, L.

FIG. 109.—SEED OF SCORPION GRASS *Myosotis arvensis*, Hoffm.

stamens—two long and two short—and fruit of four nutlets (commonly called 'seeds') at the bottom of a persistent calyx-tube.

BORAGINEÆ, like Labiatæ, have a fruit of four nutlets, but their leaves are not opposite, nor are their corrollas two-lipped. To this order belongs the **prickly comfrey** (*Symphytum asperrimum*), an introduced plant, producing an abundance of coarse herbage employed for green soiling of cattle (p. 263) or for making silage. The crop is grown from the divided rootstocks, which are planted at regular distances, and yield three or four cuttings a year. Other members of the order are the **common comfrey** (*Symphytum officinale*), the purple-reddish and cream-coloured flowers of which are seen by

the sides of streams; the **corn gromwell** (*Lithospermum arvense*), an annual weed of cornfields; the blue-flowered **borage** (*Borago officinalis*), employed to flavour claret-cup; **viper's bugloss** (*Echium vulgare*—fig. 108); the **forget-me-not** (*Myosotis palustris*), and the allied weeds known as **scorpion grasses** (*M. arvensis*, etc., fig. 109).

CHENOPODIACEÆ is the name of the order of which the **mangel wurzel, beetroot,** and **spinach** are members. The various species of **goose-foot** (*Chenopodium*) (figs. 110 and 111), which are amongst the commonest annual weeds of arable land, likewise belong to this order. The flowers of chenopodiaceous plants are small and greenish, and possess no petals.

Examine some mangel seed. The 'seed' of commerce consists of the ovary, with its seeds, imbedded in the swollen base of the perianth, which thickens and

FIG. 110.—WHITE GOOSEFOOT, *Chenopodium album*, L. With enlarged flower.

FIG. 111.—SEED OF WHITE GOOSEFOOT, *Chenopodium album*, L.

hardens as it ripens, becoming angular and somewhat woody. Hence, when a mangel or beet 'seed' is set to germinate, it is not unusual for two or three shoots to appear from it.

In cultivation, two or three young plants are likely to spring up at the same spot, and this renders the 'setting out' of the mangel plant difficult, whilst it helps to account for the frequently 'patchy' appearance of the crop. To promote regularity of sowing, the

mangel 'seed' is sometimes broken in a mill, whereby the true seeds are set free, and are thus enabled to fall more uniformly from the drill.

The mangel, the sugar beet, and the garden beet are all improved modifications of the same original wild plant (*Beta maritima*), whose natural habitat is on sea shores.

Three main types of **mangel** are cultivated—the long red, the yellow globe, and the intermediately-shaped tankard. Botanically, the mangel is far removed from the swede, which it rivals in feeding properties and excels in keeping qualities. The crop is not suited to feeding on the ground, but is best stored for spring and summer consumption (*see* p. 461). An additional reason for storing it is that it will not stand the winter if left in the ground. Mangel is sown earlier than turnips or swedes, and the crop has a longer period for its growth; it has a much more deeply penetrating tap-root, throws out a less proportion of its feeding roots near the surface, and exposes a comparatively large area of leaf to the atmosphere. With its more extended root range it is less dependent on frequency of rain when growth is once well established, and it thrives under a higher temperature than the turnip. Hence the midland, eastern, and southern districts are much more suitable for the crop than the north-west or north of England, or than Scotland, where it is comparatively little grown. Where, however, soil and climate are favourable, much heavier crops can be grown than of turnips, provided very large dressings of farmyard manure are employed. The proportion of leaf to root is, as a rule, very much less in the mangel than in the turnip, but more than in the swede.

The **garden beet** is grown as a salad plant, and its dark crimson colour renders it a suitable addition to red cabbage in the pickle-jar. The **sugar beet** is much cultivated in Germany, Austria, and France, sugar being extracted from the juice of the roots, and the refuse pulp affording a valuable cattle food. It is a much smaller root than the mangel, and as it grows almost entirely buried in the soil it is a more expensive crop

to raise. On the stronger soils it is necessary to raise them with forks, or with some special digging machine, as is done on the Continent. Another point to be noticed is that the smaller and rougher roots generally contain the higher percentage of sugar, and though these are consequently best for commercial purposes, they give a comparatively small yield per acre.

POLYGONACEÆ is an order rendered sufficiently familiar by such well-known weeds as the docks and sorrels, together with the snakeweed (bistort) and knotgrass. Like the chenopods they have incomplete flowers, the petals being absent, but the sepals frequently assuming a reddish, pinkish, or whitish tinge. The order is characterized by the presence of a membranous sheath (a form of *stipule*) surrounding the stem at the base of each leaf-stalk, and by the fruit having the appearance of a polished triangular nutlet—like a very small beech-nut. The presence of dock and sorrel 'seeds' (figs. 112 and 113) in samples of cultivated seeds is thereby easily detected.

FIG. 112.—'SEED' OF COMMON SORREL, *Rumex Acetosa*, L.

FIG. 113.—'SEED' OF SHEEP'S SORREL, *Rumex Acetosella*, L.

Buckwheat (*Polygonum Fagopyrum*) and **rhubarb** (*Rheum hybridum*) are two polygonaceous plants, neither of them native, cultivated in Britain. The black triangular 'seeds' of buckwheat are occasionally sown to afford a crop either for ploughing in green or for folding with sheep. The seed is valued as food for poultry and pheasants. Rhubarb, grown for the sake of its succulent leaf-stalk, containing oxalic acid, affords an excellent example of the sheathing stipules of the order.

The **docks** and **sorrels** (species of *Rumex*) are all perennial weeds, growing from stout rootstocks, which require to be pulled up bodily in order to suppress these plants. This is the operation of 'docking,' frequently necessary amongst growing crops of corn. Docks and

sorrels are common weeds of grass land, more of hay fields than of pastures.

Knot-grass (*Polygonum aviculare*) (fig. 114)—often called 'redshank' from the colour of the sheathing stipules—and the **climbing bistort** (*P. Convolvulus*), with its dark leaves and its convolvulus-like habit, are amongst the commonest weeds of cornfields, and often occur on other arable land.

URTICACEÆ, the stinging-nettle family, is the order to which British botanists refer the **hop** (*Humulus Lupulus*)

FIG. 114.—KNOT-GRASS, *Polygonum aviculare*, L.

FIG. 115.—HOP, *Humulus Lupulus*, L.

(fig. 115). This plant grows wild in the hedgerows, but its cultivation is practised chiefly in Kent, the only other counties in which hops are grown to any extent being Sussex, Surrey, Hants, Hereford, and Worcester. In 1913 there were 35,676 acres of hops in England, of which Kent alone grew 21,944 acres, or more than three-fifths of the whole.

Hops are a very expensive crop to grow, are specially liable to insect attacks and fungoid diseases, and are cultivated differently from any other English crop. The plant has a twining habit, and stout poles are thrust

into the 'hills' in spring in order to give support to the bine, the young shoots of which are at the outset tied to the poles. The lateral growth of the bine is encouraged by strings of coco-nut fibre stretching from pole to pole, whereby the side shoots get plenty of light and air.

Systems of 'wire training' are now commonly used, the wires being strained to posts permanently fixed in the ground. This is sometimes spoken of as the 'Telegraph system,' and has many advantages over the old poles, as there is a better access of light and air to the growing bines, and it is easier to wash the hops when trained on wire. Again, the picking from the wire and stringwork system is simpler, as it is only necessary to cut the string when throwing the bine down. In picking from poles, on the other hand, the bine must be cut first, and this premature cutting often involves bleeding and consequent weakness.

The hop has unisexual flowers, the male plants carrying the staminate flowers in loose pale green panicles, whilst in the female plants the pistillate flowers are gathered into heads made up of closely packed bracts. It is in these that the bitter principle of the hop (*lupulin*) is found, and, after flowering is over, they enlarge into the head or 'cone' which is gathered by the hop-pickers.

LILIACEÆ constitute a beautiful group of flowering plants, of which the lily, tulip, and hyacinth are familiar examples. The flowers possess three sepals and three petals much alike in shape, size, and colour. There are six stamens and three carpels, the latter uniting to form a three-chambered superior ovary containing numerous seeds.

The **onion** (*Allium Cepa*), which belongs to this order, is cultivated as a garden crop rather than a field crop. It is grown for its tunicated bulb (similar to fig. 60), the white fleshy overlapping scales of which are made up of the bases of the leaves. It is used either as a vegetable, as a salad, or for pickling. The crop requires considerable care in cultivation, a well-prepared seed-bed especially being necessary. The seed, in germinat-

ing, keeps the tip of the shoot inside the seed-coat for some time after emergence above the ground. The **shallot** (*Allium ascalonicum*) is a variety of onion with a flat side, due to two or three bulbs growing together. The **leek** (*Allium Porrum*) does not bulb proportionately to the same extent as the onion. It is used chiefly for cooking.

Asparagus (*Asparagus officinalis*) is a liliaceous plant, with a creeping matted rootstock throwing up annual shoots, which are eaten young as a culinary vegetable. The culture is of quite a special character. Good prices are obtained in early spring for asparagus, which is tied up in bundles for the market. It is a native of maritime coasts.

The **wild onion,** or **crow garlic** (*Allium vineale*), is an exceedingly objectionable weed in cornfields, as the presence of garlic in a sample of wheat detracts largely from its value. Garlic is easily recognized, both by its general resemblance to the onion and by its unmistakable odour. It is cleared out from a growing crop by the expensive process of hand-pulling.

FIG. 116.—MEADOW SAFFRON, *Colchicum autumnale*, L. With pistil and fruit enlarged.

Meadow saffron (*Colchicum autumnale*) (fig. 116) is a poisonous weed that grows occasionally in meadows and pastures. The slender leaves alone are thrown up in spring, and the pale, purple flowers appear in autumn, after the leaves have died down.

GRAMINEÆ.—Of the natural orders of plants this is by far the most important and the most useful to the agriculturist, including as it does all cereals and grasses. Wheat, barley, oats, rye, maize, rice, and millet are

gramineous plants cultivated mainly for the sake of their grain. Meadow and pasture grasses, such as rye grass, cocksfoot, foxtail, timothy, etc., are gramineous plants grown for their nutritious herbage, which is either consumed green, or is first converted into hay or silage. The sugar-cane and the bamboo are examples of gramineous plants grown for yet other purposes.

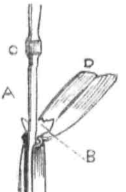


FIG. 117.—PART OF UPRIGHT STEM OF GRASS PLANT.

A, culm, seen within the split leaf-sheath.
B, ligule.
C, C, joints.
D, part of lamina or leaf-blade.

Pull up a **grass plant** by the root and examine it. Notice that the **root** consists of a large number of more or less coarse threads, called *root-fibres*. In some species, as barley, these spread out near the surface of the ground; in others, as wheat, they penetrate more vertically into the soil.

The upright **stem** in a grass plant is called the *culm* or *haulm* (fig. 117). In most species the culm is hollow, save at the bases of the leaf-sheaths—the *joints*—where it is solid. Many grasses develop a prostrate stem, or *stolon* (fig. 150), which at intervals sends rootlets downwards and leaf-shoots upwards, and thus gives rise to a number of independent centres of growth. Such grasses are described as stoloniferous; fiorin (p. 236) and meadow foxtail (p. 239) are examples.

Observe that the **leaf** in most grasses is long, narrow, and strap-shaped, coming to a point at its free end. It varies in different species between the fine slender (*setaceous* or bristly) leaf seen in sheep's fescue, and the broad flat leaf characteristic of cocksfoot, or of the great reed (fig. 120). Hold a grass leaf between the eye and the light, and notice the parallel ribs extending from tip to base. Follow the leaf downwards to where it embraces the stem by means of its *leaf-sheath*. In most kinds of grasses the leaf-sheath is split

down the front. Closely similar grasses are sometimes distinguished by the *rough* or *smooth* surface of the sheath.

By pulling the leaf slightly away from the stem, and looking at the place where the leaf joins its sheath, a thin whitish outgrowth is in most species brought into view. This is the **ligule** (fig. 117), and it is worthy of note, because, on account of variations in its size and shape, it is frequently of use in affording a means of distinguishing between grasses that are otherwise much alike. For example, grow some plants of wheat, barley, and oats, till they are about six inches high, and then compare their ligules. That of wheat not only surrounds the culm, but its ends overlap, and they are *hairy;* in barley the ends of the ligule similarly overlap or cross each other, but they are *naked;* whilst in oats the ligule is so short as to extend only part of the way round the culm. Notice, also, the ligules in the three common meadow grasses:—

Rough-stalked meadow grass (*Poa trivialis*), ligule long and pointed.
Smooth-stalked meadow grass (*Poa pratensis*), ligule blunt.
Wood meadow grass (*Poa nemoralis*), ligule none, absent.

Again:—

Fine bent grass (*Agrostis vulgaris*), ligule short, blunt.
Marsh bent grass (*Agrostis alba*), ligule long, acute.

The most distinctive characters of grasses are to be found in the flowers, and for these the **ear** or **panicle** (the *inflorescence*) must be examined. Take an ear of some large-flowered grass, such as oats. The nodding structures at the ends of the delicate branches are called **spikelets.** Break off a spikelet and examine it. At its base are seen two large boat-shaped leaves—called the empty or **outer glumes**—almost, but not quite, opposite each other. Between these outer glumes are embraced two or more little flowers—or florets, as they are better termed, on account of their small size. Each floret has, at the base, two chaffy leaves, nearly opposite to each other. The larger and lower of these is called the **flowering glume,** the smaller and upper is the **palea** or

pale (figs. 145-6), though sometimes they are called the *outer pale* (*i.e.*, the flowering glume) and the *inner pale* respectively. The flowering glume at its edges embraces the pale. An awn, or bristle, is seen to arise from the middle of the back of the flowering glume of the lowest floret. Between the flowering glume and pale are contained (fig. 118) the three stamens, from the anther-lobes of which comes the male fertilizing material or pollen. In the heart of the floret, between the filaments or stalks of the stamens, is seen the ovary, which eventually ripens into the grain.

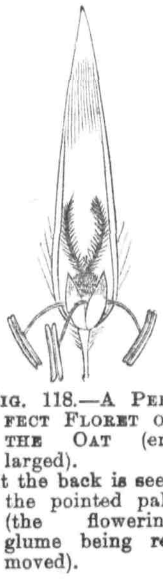


FIG. 118.—A PERFECT FLORET OF THE OAT (enlarged).
At the back is seen the pointed pale (the flowering glume being removed).

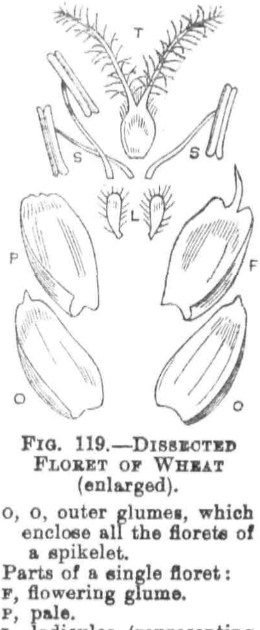


FIG. 119.—DISSECTED FLORET OF WHEAT (enlarged).

O, O, outer glumes, which enclose all the florets of a spikelet.

Parts of a single floret:

F, flowering glume.
P, pale.
L, lodicules (representing perianth of ordinary flowers.
S, the three stamens.
T, the pistil, comprising an ovary surmounted by the two feathery styles.

In most grasses the florets are much smaller than they are in the oat, and there exist various modifications of the parts just enumerated. In the wheat-plant, however, the florets (fig. 119) are large, but the spikelets which contain them have no stalks. The presence or absence of stalks to the spikelets determines, to a great extent, the appearance of the ear or panicle of a grass. Where the spikelets are not supported by stalks, but rest directly upon the stem or axis, there results the close narrow ear seen in wheat, couch grass (fig. 158), barley, barley grasses (fig. 160), rye, and rye grasses (figs. 148-9). Where the spikelets are upon long stalks, which spread outward from the axis, such panicles as those of oats (fig. 189), oat grasses (fig. 144), meadow grasses (figs. 141-3), fescue grasses (figs. 131-2, and 135-6), brome grasses (figs. 156-7), bent grasses (figs. 137-8), quaking grasses, hair grasses (fig. 159), Yorkshire fog (fig. 161), reeds (fig. 120), and cocksfoot (fig. 124) result. Sometimes the stalks of the spikelets are very short, and lie so closely against the stem that the panicle looks as if the spikelets were without stalks, though examination shows this is not really the case; examples are seen in dogstail (fig. 125), foxtail (fig. 139), timothy (fig. 155), and, to a less extent, in sweet vernal (fig. 153). It will be noticed that just as the ear or panicle of a grass or cereal is made up of spikelets, so is each spikelet made up of one or more florets.

FIG. 120.—COMMON REED, *Phragmites communis*, Trin. With enlarged spikelet and floret.

In order that there may be no uncertainty as to what

is meant by a **spikelet,** look at fig. 131 (meadow fescue grass), and count the spikelets, which, in this illustration, number twenty-three. In the specimen of barren brome grass, illustrated in fig. 157, there are fourteen spikelets shown. In the specimen of perennial rye-grass (fig. 148) eighteen spikelets may be counted. In most of the illustrations of grasses, moreover, an enlarged view of a single spikelet is given.

The **awn** is a bristle which *usually* springs from the back of the flowering glume (or outer pale), above referred to as helping to enclose the floret. The awn may arise from the base (as in wavy hair grass, fig. 146), or from the middle of the back (as in sweet vernal grass), or it may be a mere prolongation of the tip (as in dogstail, fig. 127) of the flowering glume. 'Bearded' wheat is awned, beardless or smooth wheat is not awned. The awns, like the ligules, afford a means of distinguishing between species of grasses that are otherwise much alike. Thus, Italian rye grass (fig. 149) is awned; perennial rye grass (fig. 148) is usually not awned. The fescue grasses (*Festuca*, figs. 135-6) are mostly shortly awned; the meadow grasses (*Poa*, figs. 141-3) are never awned. In barren brome grass (*Bromus sterilis*, fig. 157) the awn is long; in soft brome grass (*Bromus mollis*, fig. 156) it is short. In Yorkshire fog (*Holcus lanatus*, fig. 161) the awn is hidden, in creeping soft grass (*Holcus mollis*) it is exposed.

The true seed of cereals and grasses never, as such, finds its way into commerce, the grain, as in wheat, being really the fruit. The commercial 'seed' of rye is similar to that of wheat, but in the case of barley or oats there is something more, for the flowering glume and pale have hardened on to the grain, so that the 'seed' in this case is the dried floret, in the middle of which is the fruit. The 'seed' of many grasses, as it occurs in commerce, consists similarly of the entire floret, this being the case with the 'seed' of cocksfoot (figs. 128-9), dogstail (figs. 126-7), fescues (fig. 134), rye grasses (fig. 133), meadow grasses, sweet vernal, timothy, and others. In some cases the 'seed' consists of even more than this, for it includes the entire spikelet. An

example is afforded by foxtail seed, to gather which it is only necessary to strip the spikelets (fig. 139) off the ripe ear. Hence the term 'seed,' as applied to grasses, must be understood in a special sense—the fruit or grain enveloped in 'chaff'—and as by no means implying the true botanical seed, such as is exemplified in the commercial seed of clovers, trefoils, turnips, and cabbages. In short, the term 'seed,' as applied to grasses, means simply 'that which is sown.'

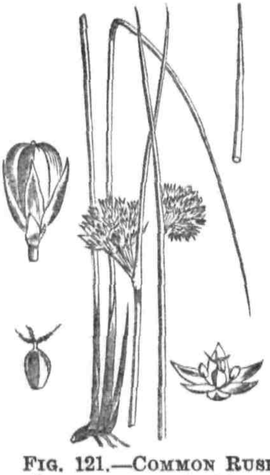


FIG. 121.—COMMON RUSH, *Juncus communis*, Meyer. With enlarged floret and fruit.

FIG. 122.—FIELD WOOD-RUSH, *Luzula campestris*, Willd. With enlarged floret and fruit.

The only commonly occurring plants which are liable to be mistaken for grasses are *rushes* (nat. ord. **JUNCACEÆ**) and *sedges* (nat. ord. **CYPERACEÆ**); they have no feeding value.

Rushes usually have dark green rounded stems, tapering to a point, and enclosing a continuous or interrupted pith. The leaves, if developed, are either flat or like the stem. The brownish flowers of rushes contain six stamens, surrounded by six scaly leaves. They are,

therefore, quite different from those of grasses, and have rather the structure of a very diminutive tulip flower. Moreover, they are never aggregated together in spikelets. The true rushes (*Juncus*, fig. 121) grow naturally on poor wet lands. The wood-rushes (*Luzula*, fig. 122) occur upon heaths, meadows, pastures, and shady places. Their foliage is more grass-like than that of the rushes, but their leaves always have a cottony appearance, due to the presence of long wavy white hairs.

FIG. 123.—PINK-LEAVED SEDGE, or 'CARNATION-GRASS,' *Carex panicea*, L. With male and female flowers enlarged.

Sedges (*Carex*, fig. 123) are at once distinguished from grasses by their solid triangular stems, by their entire leaf-sheaths, and by the absence of ligules. In *grasses* the stems are usually round and hollow, and their leaf-sheaths are split in front. The anthers of grasses are notched (figs. 118-19) at the ends; those of sedges are not. The cotton-grass or cotton-sedge (*Eriophorum*), growing on moors and bogs, develops cottony heads, which look in the distance like tufts of white wool.

The term 'grass' is erroneously applied to certain plants which are not members of the natural order Gramineæ. Thus, cotton-grass and carnation-grass (fig. 123) are really sedges. Knot-grass (fig. 114), a troublesome weed on arable land, is a near relation of the docks and sorrels. Goosegrass (fig. 165) is the cleavers, hariff, or whip-tongue, growing in hedgerows. Rib-grass is the plantain. Scorpion-grass is one of the blue-flowered forget-me-nots. Arrow-grass belongs to the water plantain family. Scurvy-grass and the whitlow-grasses are cruciferous plants. The grass of Parnassus is a member

of the saxifrage family. Cow-grass is a clover—the much-valued *Trifolium pratense perenne.*

Grasses, very closely allied to each other, may nevertheless possess widely different properties. Thus, wheat is botanically related to the troublesome weed couch-grass (fig. 158), whilst meadow foxtail (fig. 139) is allied to the field pest known as slender foxtail, or hunger-weed (fig. 140). In describing the **grasses of agricultural value** it will be convenient, therefore, to refer to the **weed-grasses** respectively allied to them. Though the characters of the panicle, spikelets, and florets afford the readiest means of identifying grasses, it must be remembered that during the greater part of the year these plants are not in flower. Hence, it is necessary to study the leaves and roots of grasses, and to endeavour to identify the several species by the characters of these alone. In many cases this is not difficult.

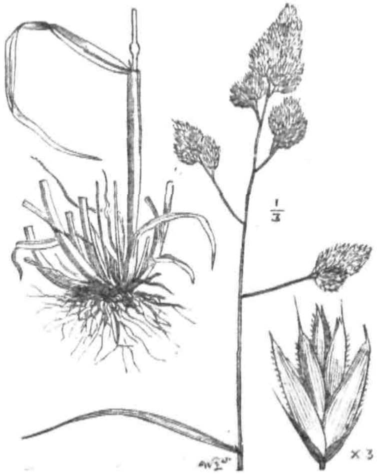


FIG. 124.—COCKSFOOT, *Dactylis glomerata*, L.
With enlarged spikelet on the right.

The cultivated grasses are here described, as a matter of convenience, in the following order: Cocksfoot, Dogstail, Fescues, Fiorin, Foxtail, Meadow Grasses, Oat Grasses, Rye Grasses, Sweet Grasses, Sweet Vernal, and Timothy. As has been intimated, however, incidental references are made to such weed-grasses as are generically allied to any of the foregoing.

Cocksfoot (*Dactylis glomerata*, L.) is easily recognized. Its spikelets are crowded together into thick clusters—hence the specific name 'glomerata'—and they are all turned to one side (fig. 124). It is a large, coarse-growing, and often unsightly plant, rough or harsh to the touch. The leaves are very characteristic—broad, thick, juicy, bluish-green, and their basal parts white and flattened near the ground. It is tall, and of quick growth. After having been once mown, and particularly if growing in a deep, rich soil, its foliage becomes luxuriant and abundant. To this latter circumstance is attributed the freedom with which it grows in orchards (whence it is termed Orchard Grass in the United States) and near farm buildings. It is less suitable for pasture than for meadow, because on account of its tufted habit it forms dense cushions or tussocks, which, owing to the strength of the stems, render the whole plant liable to become uprooted by grazing animals. Cocksfoot has a fibrous, much-branched, and deeply descending root, so that it is scarcely sensible to drought, provided the soil is sufficiently deep. It grows successfully in almost all soils, except dry sands and heath lands, generally thriving better in damp and heavy soils than in such as are light and dry.

Cocksfoot is never sown alone, for its tufted growth would result in the formation of a patchy irregular sward. It should be cut, if practicable, before flowering; otherwise the stems become hard and woody, and therefore less acceptable to animals as fodder. In meadows where cocksfoot makes up the chief part of the herbage, the time for commencing to mow should be determined by the condition of this grass. It furnishes a very abundant aftermath, or second growth.

The commonest impurities of cocksfoot seed (figs. 128 and 129), namely, the seeds of meadow fescue (fig. 134), yellow oat grass (fig. 145), and rye grass (fig. 133), are far from being injurious, and two of them are of higher commercial value than cocksfoot seed itself. More prejudicial are the seeds of brome grass and of certain weeds of the composite family, particularly ox-eyes

(fig. 106), groundsel, ragworts, nippleworts, and hawkweeds. Seeds of umbelliferous weeds are also found in badly cleaned samples of cocksfoot.

Dogstail (*Cynosurus cristatus*, L.).—Crested dogstail grass, though of sparse habit, aids in the production of a good 'sole' in the turf of pastures. It is essentially a pastoral plant, and is not of great value in the hayfield. In association with the narrow-leaved fescues it is an important constituent of many of the best sheep pastures, while its withered culms may be seen in quantity at the fall of the year in old deer-parks, unless the turf has been closely grazed in spring and early summer. The appearance of the panicle is so characteristic (fig. 125) that it is not likely to be confounded with any other native species; its peculiarity is the presence of a pectinate (or comb-like) bract at the outer base of each spikelet. The leaves are rather narrow and taper upwards, and the sheaths near the ground have a yellowish white colour. Dogstail is widely distributed in the pastures of the British Isles, but it never occupies a leading place in the bulk of herbage produced. The plant seems to be most at home on compact, dry soils, and thrives above a chalk subsoil. The roots are hardy and penetrate deeply, hence dogstail is little susceptible to drought.

FIG. 125.—DOGSTAIL, *Cynosurus cristatus*, L.
With enlarged spikelet and, on left, two of the pectinate bracts.

The seed of dogstail (figs. 126-7) is easily identified by its elegant attenuated form, and its bright yellow colouring. The usual impurities are seeds of Yorkshire fog (the small shining grey-shelled 'seeds' that have fallen from the dried spikelet), sheep's fescue, and blue moor-grass (fig. 130).

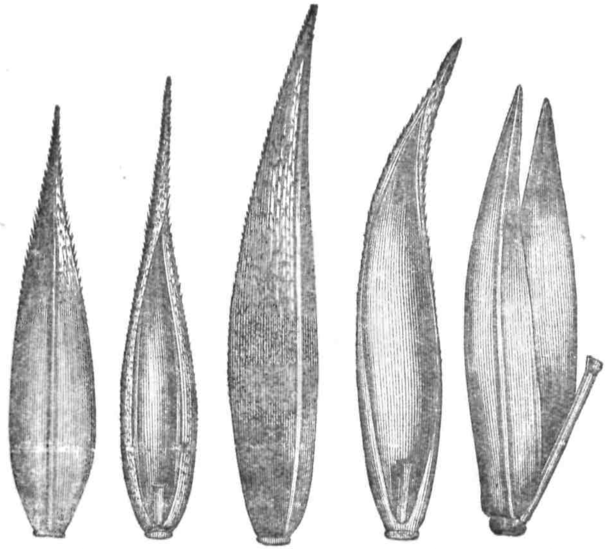


FIG. 126. FIG. 127. FIG. 128. FIG. 129. FIG. 130.
'Seeds' (much enlarged) of (figs. 126, 127) dogstail; (figs. 128, 129) cocksfoot; and (fig. 130) purple Molinia (blue moor-grass).

The **Fescues** (*Festuca*) comprise an important group of grasses, several of which are of recognized agricultural value. They may be conveniently divided into the broad-leaved fescues and the narrow-leaved fescues.

The *broad-leaved* forms include **Meadow Fescue** (*Festuca pratensis*, Huds.), **Tall Fescue** (*F. elatior*, L.), and **Spiked Fescue** (*F. loliacea*, Huds.). These are all, however, modifications of one type, and that type is best represented by meadow fescue (fig. 131),

which is a grass of moderate size, with flat rich green leaves, and a nodding panicle turned to one side. Tall fescue is larger and more robust, often attaining a height of six feet, and found naturally on the borders of water courses. Spiked fescue (fig. 132) is a more slender plant than meadow fescue, and in its panicle the spikelets are either without stalks, or have only short ones, thus conferring upon the ear some external resemblance to the ear of perennial rye grass (*Lolium perenne*,

Fig. 131.—Meadow Fescue, *Festuca pratensis*, Huds. ith a single spikelet on the right.

Fig. 132.—Spiked Fescu *Festuca loliacea*, Huds. With a single spikelet on the

fig. 148), whence the specific name of 'loliacea.' The seeds of meadow fescue and rye grass are much alike in appearance. On comparing the two (figs. 133-4), it is seen, however, that in meadow fescue the fragment of stalk at the base is usually longer, slightly separated lengthwise from the pale, circular in transverse section, somewhat attenuated in the middle and thickened at the free end. In rye grass, on the other hand, the

corresponding structure is usually shorter, closely applied to the pale, elliptical in transverse section, and not narrow in the middle.

Meadow fescue is a valuable constituent both of meadows and of pastures, though it is much rarer in old pastures than was at one time supposed. It is rather a deep-rooting plant, and thrives best on damp clayey or marshy soils. It is an admirable grass for irrigated meadows, and, on the other hand, has not much capacity for withstanding drought. Its habit of growth is in compact tufts, from which, in favourable situations, the stems rise to a height of from two to three feet, and are furnished with long broad leaves.

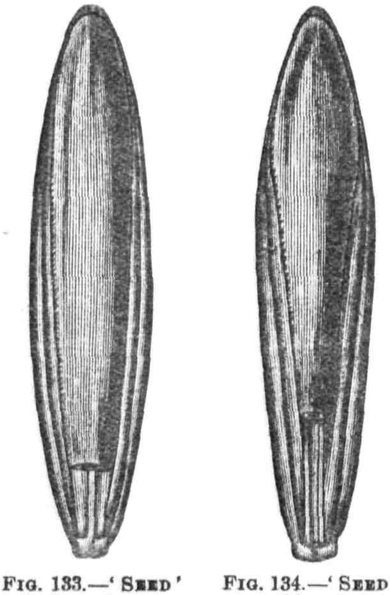


FIG. 133.—'SEED' OF RYE GRASS.

FIG. 134.—'SEED' OF MEADOW FESCUE.

(Both ten times the natural size.)

Sheep's fescue (*Festuca ovina*, L.) may be taken as the type of the *narrow-leaved* fescues. It forms a thick tufted herbage (fig. 135) of very fine leaves—so fine that they are often described as setaceous (Lat. *seta*, a bristle), and in the United States this grass is known as Pine Bunch Grass. It is a common grass on light limestone pastures, and on chalk downs grazed by sheep, and in such situations it helps to form a close carpet of turf.

The panicle is not unlike that of some of the meadow grasses (*Poa*, figs. 141-3), from which it may be distinguished by its short awns, the meadow grasses being free from awns. *Festuca ovina* is susceptible of considerable variations, determined by circumstances of soil, situation, and climate. The commonest modifications are:—

Festuca duriuscula	Hard fescue.
Festuca rubra	Red fescue.
Festuca heterophylla	Various-leaved fescue.
Festuca tenuifolia	Fine-leaved fescue.

Hard fescue (*Festuca duriuscula*, L.) is so named in allusion to the fact that the spikelets become hard as

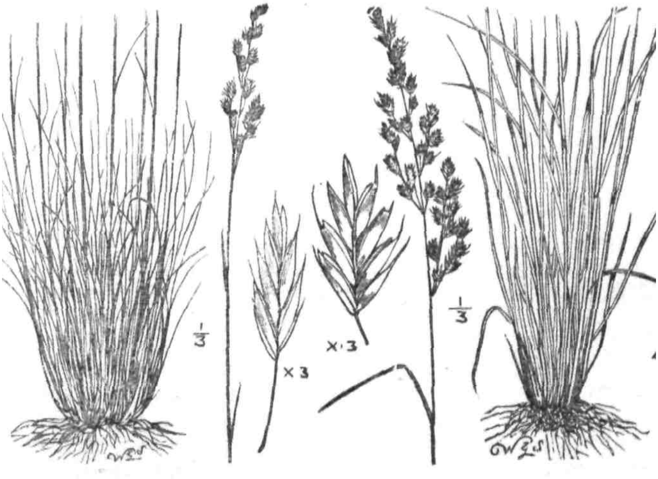


FIG. 135.—SHEEP'S FESCUE, *Festuca ovina*, L. [Wi]th enlarged spikelet on the right.

FIG. 136.—HARD FESCUE, *Festuca duriuscula*, L. With enlarged spikelet on the le[ft].

they ripen. The grass (fig. 136) is a valuable constituent of sheep pastures, where it helps to form a close bottom to the turf. Its habit, however, is not tufted, and its

herbage is tender, juicy, and relished by stock. The leaves are of a deep bluish-green colour, stiff, and rolled up almost into a cylinder. Hard fescue seed may be usefully included in mixtures for permanent pastures upon all soils that are not very wet. Being the commonest of the narrow-leaved fescues its seed is the cheapest.

Red fescue (*Festuca rubra*, L.) derives its name from the colour of the sheaths of the lower leaves, which, when the plant is spread open for the purpose, are seen to be of a dull red. A more robust plant than hard fescue, it has at the same time a creeping habit, which helps it to withstand drought, and suits it to poor soils. Like most of the narrow-leaved fescues, this variety does not make sufficient bulk to be of much use in the hayfield, but it is unquestionably serviceable as a constituent of the bottom herbage in pastures, where it is readily grazed by stock. Its seeds are larger than those of hard fescues.

Various-leaved fescue (*Festuca heterophylla*) has, as its name implies, leaves which are not uniform in size and shape. Its foliage varies somewhat between the narrow-leaved and broad-leaved types of fescue. The upper leaves are broad, but the root-leaves are harsh and slender, and are enveloped in loose brown sheaths, whilst the general habit of the plant is tufted. It comes into profit fairly early in the season, and thrives best upon calcareous soils, even when they are moist or shady.

Fine-leaved fescue, or slender-leaved sheep's fescue (*Festuca tenuifolia*), is a typical constituent of sheep pastures. Its folded, thread-like leaves are so attenuated that the entire plant presents a wiry appearance. Nevertheless, it is juicy and palatable, and there is no grass more relished by sheep. It is deep-rooted, and is naturally suited to poor, dry uplands. It is useless to sow it on rich soils, as it gradually disappears.

Fiorin (*Agrostis alba*, L., var. *stolonifera*), or creeping bent grass, is a stout broad-leaved grass, sending out prostrate stems or stolons (p. 150), which creep amongst the other herbage, and develop rootlets wherever an

opportunity offers. Hence, under favourable circumstances, the plant increases with considerable rapidity. Its interrupted panicle (fig. 137) of innumerable small spikelets is characterized by the well-defined intervals between the points from which the clusters of branches arise. Fiorin thrives in moist poor soils, both sandy and peaty. It can hardly be described as a favourite food for cattle, but it is useful in that it affords a green bite far into the autumn. It cannot be recommended as

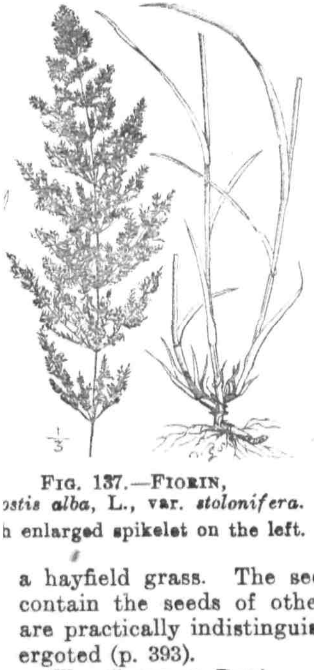


FIG. 137.—FIORIN,
ostis alba, L., var. *stolonifera*.
h enlarged spikelet on the left.

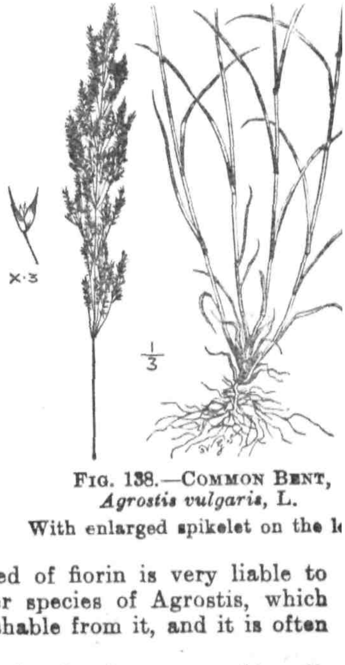


FIG. 138.—COMMON BENT,
Agrostis vulgaris, L.
With enlarged spikelet on the l

a hayfield grass. The seed of fiorin is very liable to contain the seeds of other species of Agrostis, which are practically indistinguishable from it, and it is often ergoted (p. 393).

The **Common Bent**, or the fine bent grass (*Agrostis vulgaris*, L., fig. 138), and the **Marsh Bent** (*Agrostis alba*, L.) are two weed grasses, often included in the common term, twitch, or squitch. They occur abundantly in poor meadows, and as weeds in some descriptions of arable

land. When a wheat crop is cut, the land is often found to be covered with bent grasses.

Meadow Foxtail (*Alopecurus pratensis*, L., fig. 139) is one of the early grasses, and may often be found in ear by the middle of April. The ear has much the appearance of a round tail ending in a point, and if drawn from base to tip, between finger and thumb, it feels soft and silky. By doubling the ear upon itself at about the middle of its length, it will be seen that each spikelet has a very short stalk, and that the spikelets are thickly crowded along the axis. The silvery grey colour of the ear is largely due to the silky hair or bristle (the awn), which springs from the flowering glume of the solitary flower within each spikelet. The leaves are soft, green, succulent, and very numerous; they are long, broad, and strongly veined. Foxtail throws up much herbage in the early spring, and thus affords valuable grazing at a period before many of the other grasses are ready. Though a tall fine grass, it is less robust than cocksfoot; at the same time it is less unsightly.

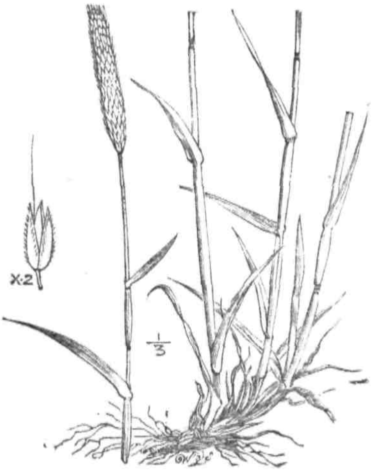


FIG. 139.—MEADOW FOXTAIL, *Alopecurus pratensis*, L. With enlarged spikelet on the left.

A perennial grass, of early growth, and affording abundance of excellent forage, this is a most useful species for permanent pasture. Scarcely any grass resists better the cold of winter, and even late frosts affect it but slightly. It appears to thrive equally well

in sunny and in shady situations, and therefore grows luxuriantly in orchards, where indeed its precocious growth may become well advanced before leaves appear upon the fruit-trees to intercept the sun's rays. On thin, light soils it gradually disappears, whilst it flourishes best on deep heavy lands. On damp soils and on irrigated meadows it does equally well, but stagnant water is inimical to it.

Meadow foxtail spreads itself by means of short prostrate stolons, given off in all directions from the base of its stem. These stolons develop rootlets at intervals, and consequently this grass is quite free from that tufted habit which prevents such grasses as cocksfoot from forming an even sward. Meadow foxtail shares with sweet vernal the distinction of being the earliest-flowering of all the useful grasses. On a good soil it is quite capable of yielding three cuts in the year. In the year of sowing, however, the yield is only moderate; it is better in the second year, and acquires its greatest development in the third year. As a forage crop, therefore, foxtail is never grown by itself. Associated, however, with meadow fescue, cocksfoot, rye grass, and alsike clover, it is well adapted for several years' ley, and for permanent pasture.

The 'seed' of meadow foxtail, as it occurs in commerce, consists of the spikelet (*see* fig. 139) with its contained structures. It is frequently gathered unripe, and this accounts for the low germinating percentage which samples often give.

Common impurities of foxtail seeds are the 'seeds' of Yorkshire fog (*Holcus lanatus*, fig. 161), and creeping soft grass (*Holcus mollis*). Though possessing a close apparent resemblance to the seed of foxtail, they may yet be easily distinguished from it, both by the character and distribution of the fine hairs, or cilia, upon the glumes which enclose the grain, and by the nature of the awn. Sometimes it happens that meadow-foxtail seed is adulterated with the seed of its near ally (*Alopecurus agrestis*, L., fig. 140), variously termed *slender foxtail, black bent*, or *hunger-weed*. The 'seed' of this latter, however, is less ciliated along the keels of the outer

glumes, and is usually darker in appearance than the seed of meadow foxtail. One other adulterant, only found, however, in foreign foxtail seed, is the seed of the exotic ciliated melic grass, *Melica ciliata*, L., but this is at once recognized by the extraordinary extent to which its glumes are fringed with delicate white hairs (*cilia*).

Floating foxtail (*Alopecurus geniculatus*, L.) is an elegant little grass found in water meadows, shallow ponds, and other damp situations. Its stem is too weak to grow upright, and it therefore rests upon the ground or upon the adjacent herbage, being recognizable by the sharp joints, or 'knees,' which give to it a zigzag appearance. When in full flower, the pollen covers its neat and shapely little ear with an orange-brown dust. Floating foxtail is never very abundant; and though not an objectionable grass in the moist localities which it frequents, it cannot be said to possess any special agricultural value, nor is its seed to be obtained upon the market.

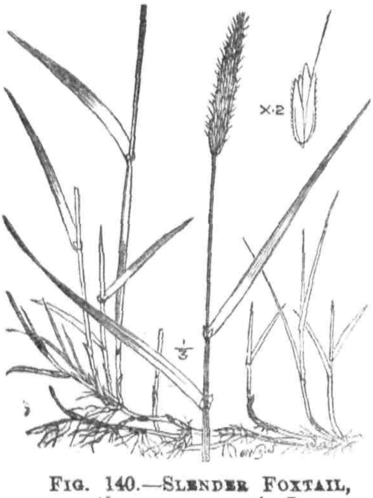


FIG. 140.—SLENDER FOXTAIL, *Alopecurus agrestis*, L.
With enlarged spikelet on the right.

Slender foxtail (*Alopecurus agrestis*, L., fig. 140) is one of the worst pests of the farm. It is a troublesome weed of arable land, especially in cornfields, but rarely invades the meadow or pasture. It possesses the general habit of the valuable meadow foxtail, but is less robust, and its ear, besides being more slender, is blotched with

black—hence the name of *black bent* commonly applied to it. Another familiar name, and one indicative of its bad character, is that of *hunger-weed*. It may be found in ear in May and June, and, if not removed before it sheds its seed, further trouble may be looked for in the following season. Cases are recorded in which fields of wheat have been quite destroyed by this pest. A caution has already been given as to the occurrence of its seed in samples of meadow-foxtail seed.

Meadow grasses (*Poa*) are characterized by the graceful tree-like branching of the panicle. In general appearance they are somewhat suggestive of the fescues (figs. 135-6), but they never bear awns, as many of the fescues do. The most widely distributed member of the group, the annual meadow grass (*Poa annua*, L., fig. 141), is a weed springing up wherever opportunity may offer. It invades bare spots in pastures, occurs in gateways and on gravel walks, grows in the crevices between paving stones, and flourishes on walls and roofs. An examination of a specimen of annual meadow grass will bring into view the leading characters of the genus Poa. Near the ground the stems are flattened, the leaves are short with blunt ends, whilst the ligule is long, pointed, whitish, and clasps the stem. The whole plant is limp and pale-coloured, and the leaves are often waved. Its small size, and the brief duration

Fig. 141.—Annual Meadow Grass, *Poa annua*, L.
With enlarged spikelet on the left.

of its life, serve to render *Poa annua* practically valueless to the farmer.

The species of Poa of agricultural interest are the smooth-stalked meadow grass, the rough-stalked meadow grass, and the wood meadow grass. Notwithstanding their general similarity, it is not difficult to distinguish between these three species. For example, the ligule (*see* p. 223) is long and pointed in *Poa trivialis*, obtuse but prominent in *Poa pratensis*, and practically absent in *Poa nemoralis*. The leaves of *Poa pratensis* are broader and blunter than those of *Poa trivialis*. If the plant is drawn through the hand, *Poa pratensis* is found to be smooth, whilst *Poa trivialis* is rough.

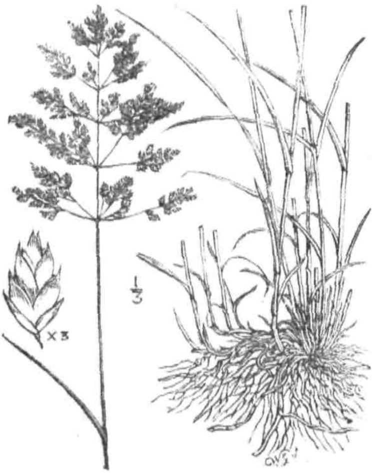


FIG. 142.—SMOOTH-STALKED MEADOW GRASS, *Poa pratensis*, L.
With enlarged spikelet on the left.

Smooth - stalked meadow grass (*Poa pratensis*, L., fig. 142) thrives naturally upon dry soils of good quality. It is rather a surface-rooted than a deep-rooted plant, is of creeping habit, and withstands drought. Being a grass of early growth, it is, on that account, a valuable constituent of dry pastures. When raised from seed its produce during the first year is but small. This is the Kentucky Blue Grass of the United States.
p. 223) is long and pointed in *Poa trivialis*, obtuse but
143), formerly called Orcheston Grass, prefers strong moist soils, and is a conspicuous ingredient of the herbage of deep rich pastures. It is, perhaps, less hardy than *Poa pratensis*, and it is 'particularly addicted to

shady situations, so that, in pastures and meadows where it occurs, it may generally be found in abundance beneath trees. Fine robust specimens occasionally spring up in the rich soil of kitchen gardens, especially amongst bush fruit.

Wood meadow grass, or evergreen meadow grass (*Poa nemoralis*, L.), is less common than the two preceding species, whilst the costliness of pure samples of the seed operates against its extensive use for agricultural purposes.

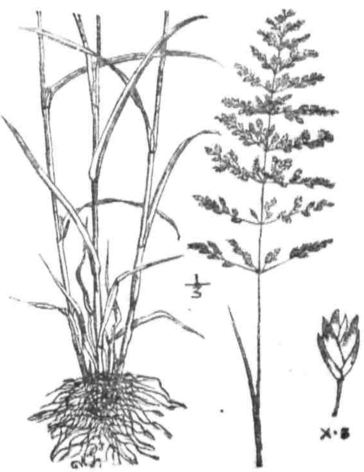


FIG. 143.—ROUGH-STALKED MEADOW GRASS, *Poa trivialis*, L. With enlarged spikelet on the right.

There is considerable similarity amongst the seeds of these three Poas. They are all 'webbed' at the base—those of *Poa pratensis* most, and those of *Poa nemoralis* least—though in some samples the web has been removed by the webbing machine. In the case of *Poa pratensis*, indeed, the woolly 'webs' cause the seeds to adhere together in fluffy masses. Amongst the impurities or adulterants in samples of Poa seeds are the seeds of annual meadow grass, of tufted hair grass (*Aira cæspitosa*, L.), and of blue moor grass (*Molinia cærulea*, Moench, fig. 130). What the buyer has chiefly to guard against, however, is the risk of accepting the seed of one species of Poa for that of another and more expensive kind.

Oat grasses belong to the same genus (*Avena*) as the cereal oats, which some of the native species closely resemble in habit, though they are usually inferior in

size. The most important species are yellow oat grass and tall oat grass, both of which are of agricultural value; and downy oat grass, narrow-leaved oat grass, and wild oat grass, which are weeds.

Yellow oat grass, or golden oat grass (*Avena flavescens*, L.), is one of the most graceful of the British grasses (fig. 144). Its leaves are slender, flat, pale green, and covered with short hairs, which can easily be seen by holding a specimen up to the light. The stem is clothed with delicate hairs pointing downwards, which help in distinguishing the grass before it protrudes its ear. The panicle is of a shining yellow colour, and glitters in the sun. Up to the time of flowering the ear is very compact, and is beautifully shaded with green and gold, whilst the delicate silky awns look like streaks of silver. As the flowers develop, the entire panicle spreads out into a tree-like form, and it is at this stage that *Avena flavescens* forms one of the most elegant midsummer objects in meadows. When the blooming time is over, and the seeds begin to ripen, the panicle closes up again, its lovely colours disappear, and it becomes brown and withered. If panicles in the three stages—before flowering, in bloom, and after flowering—are placed side by side, it is at first difficult to believe that they belong to the same species. *Avena flavescens* is a valuable grass,

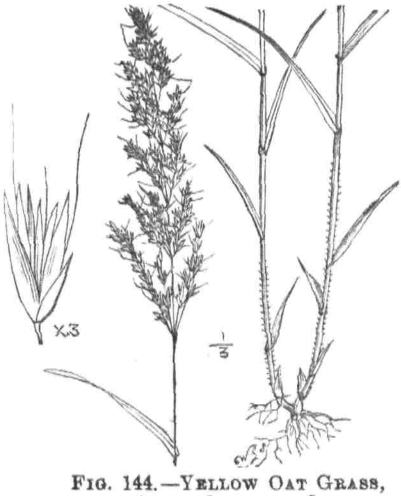
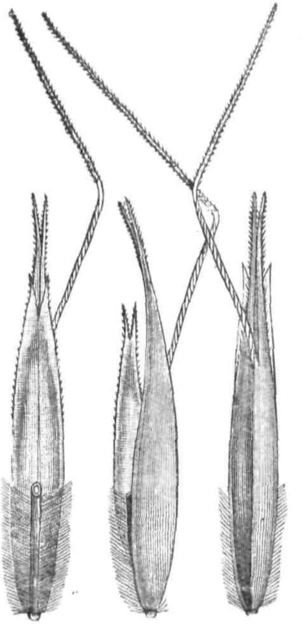


FIG. 144.—YELLOW OAT GRASS, *Avena flavescens*, L.
With enlarged spikelet on the left.

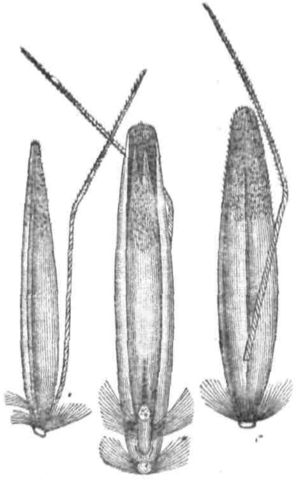
both for forage and for hay. It occurs naturally in pastures, hayfields, and water-meadows, in all of which it is a desirable constituent. Its seed (fig. 145) is costly, and that of the wavy hair grass (*Aira flexuosa*, L., fig. 146), which somewhat



A B C

FIG. 145.—'SEED' OF YELLOW OAT GRASS (enlarged).

A, inner face, showing pedicel or stalk of next 'seed,' with a *row* of hairs on each side.
B, side view, showing on the right the flowering glume, with its twisted awn arising from *above the middle* of the back, and its cleft tip; and, on the left, the pale with its free end cleft.
C, back view.
In A the pale faces the observer, and in C the flowering glume.



B A C

FIG. 146.—'SEED' OF WAVY HAIR GRASS (enlarged).

A, inner face, showing pedicel or stalk of next 'seed,' with a *tuft* of hairs on each side.
B, side view, showing on the right the flowering glume, with its twisted awn arising from *near the base* of the back; the *pale is hidden* by the flowering glume.
C, back view.
In A the pale faces the observer, and in C the flowering glume.

resembles it, has been known to be fraudulently substituted for it. The wavy hair grass is a product of poor heaths and sands, and is incapable of establishing itself in good meadows or pastures.

Tall oat grass, or false oat grass (*Avena elatior*, L., or *Arrhenatherum avenaceum*, Beauv., fig. 147), may frequently be found in or near the hedgerows bordering grasslands. Though often regarded as a weed, yet, in its proper place, and in association with other grasses, there is little doubt it possesses agricultural value. Foreign agriculturists appreciate it more than do British farmers. It thrives best on medium soils and clay loams, where, being a robust plant, it attains a height of 3 to 4 feet. It can be found in ear from early summer to late autumn, its spreading panicle being made up of pale purplish spikelets, always of a shining appearance. The bitter flavour of the plant is hardly noticeable when it is consumed in conjunction with other grasses. It is specially liable to attacks of smut (p. 390).

FIG. 147.—TALL OAT GRASS, *Avena elatior*, L. With enlarged spikelet on the right.

A variety of tall oat grass, called 'onion couch,' forms from two to five bulb-like swellings, which are modifications of the short internodes, at the base of each culm. It is sometimes a troublesome weed on arable land.

Of the weed oat grasses, the **downy oat grass** (*Avena*

pubescens) is characterized by the dense covering of close-set hairs, which impart to the plant a downy appearance. It may be found in dry pastures, especially in chalk districts. It is readily distinguished from the valuable yellow oat grass, thus:—

		Spikelets.	Ligule.
Downy oat grass	Avena pubescens, L.	Few, large. .	Long, pointed.
Yellow oat grass	Avena flavescens, L.	Many, small.	Short, blunt.

The **narrow-leaved oat grass** (*Avena pratensis*, L.) has still larger spikelets than *Avena pubescens*, but its lower leaves though harsh and rough, are not hairy. The **wild oat grass**, or havers (*Avena fatua*, L.), is a weed of cornfields, and much resembles the cultivated oat. Its spikelets are large, and the contained florets are furnished each with a long twisted awn, and with a number of reddish-brown hairs, pointing forward at the base. The stem is smooth, but hairy at the joints. This plant is an annual, growing from seed each year, and dying on the approach of winter.

The **Rye grasses** (*Lolium*) are very extensively cultivated. Perennial rye grass (*Lolium perenne*, L.) is an abundant species in rich old English pastures, and in laying land down to permanent grass it is nearly always included, the proportions varying according to circumstances. Italian rye grass (*Lolium italicum*, A. Br.) is not a grass of permanent pasture, but is profitably included in mixtures for one or two years' leys, and thrives remarkably well upon sewage-dressed lands.

Perennial rye grass (*Lolium perenne*, L., fig. 148) can scarcely be mistaken for any other species. The flattened ear looks almost as if it had been passed through a press. The spikelets, free from stalks, are given off alternately on either side of the stem, to which they are attached edgewise. Each spikelet has only one outer glume, the place of the other being, in effect, occupied by the adjacent portion of the stem or axis. The glossy dark-green leaves of rye grass glisten conspicuously in the sunlight. A prominent midrib extends along the back of each leaf, and, as the leaf is traced downwards

to its sheath, it is found to be doubled on itself like the contiguous faces of a sheet of notepaper. Moreover, the leaf-sheaths are seen to be distinctly flattened or compressed, and frequently to possess a reddish or purplish tinge at the base. By the foregoing characters rye grass, before it is in ear, can be distinguished from meadow fescue grass, the leaf of which has no prominent midrib, and is not doubled upon itself, nor are its leaf-sheaths compressed, but round. The flattened leaf-sheaths of rye grass enable the plant to accommodate itself readily to the treading of live stock, and to thrive under the hoofs of animals, and this may be one reason for the abundance of perennial rye grass in well-grazed pastures. Rye grass is likely to be found wherever the soil is rich enough to grow it. Hence it commonly occurs amongst the herbage of roadsides, where the soil is enriched with the washings and the scrapings from the surface of the road.

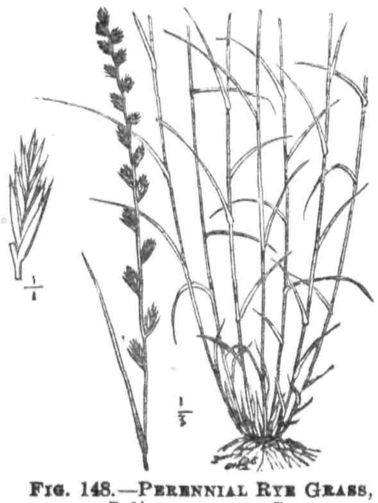


FIG. 148.—PERENNIAL RYE GRASS, *Lolium perenne*, L.
With a single spikelet on the left.

Rye grass is one of the most valuable plants of our grass lands, and in clay-land pastures it is invaluable. It *tillers*, or stools out, very freely, by which is meant that numerous leaf-buds arise above the crown of the root, and develop vigorous leafy shoots, so that the plant forms a thick close sward. It easily supports frequent grazing, or pulling by hand. Trampling or treading does it no harm, but rather enhances its useful propensity to

tiller; this is the reason it gives better results as a pasture plant than as a hayfield plant. The yield varies considerably with season and soil, and according to the manuring and preparation of the land.

Many varieties of rye grass have been named—such as Pacey's perennial, Devon eaver, etc.—but they present no well-marked or permanent differences.

Though pre-eminently a grass of permanent pasture, rye grass is also largely employed in mixtures of 'seeds' for one or two years' ley, intended to afford a hay crop, and also to provide temporary pastures. If only on account of its prompt and luxuriant tillering, rye grass should usually be included in mixtures of seeds intended for good soils.

FIG. 149.—ITALIAN RYE GRASS, *Lolium italicum*.
With a single spikelet on the right.

The seed of commerce (fig. 133) comes chiefly from Scotland and the North of Ireland, where rye grass is cultivated upon a large scale. It is collected by the seed merchants, and cleaned a second time, special care being taken to remove seeds of Yorkshire fog (*Holcus lanatus*, fig. 161), soft brome (*Bromus mollis*, fig. 156), and rat's-tail fescue (*Festuca sciuroides*). Rye-grass seed is also liable to contain seeds of plantain (figs. 171-2), buttercup, and sorrel (figs. 112-13). On account of its low price, it runs but little risk of adulteration. Nevertheless the seed of soft brome is sometimes sold in bulk as that of rye grass, but the fraud is one which is easy to discover. It use more often to happen that rye-grass seed was

itself substituted for an apparently similar but more expensive seed, that of meadow fescue, for the sake of the extra profit. (*See* figs. 133-4.) The rye-grass seed itself is classified into several commercial sorts, according to weight, purity, and germinating capacity. As the better qualities possess, in general, a greater weight, it is the weight which serves in England as a guide to the value of the seed.

Italian rye grass (*Lolium italicum*) is a larger and more robust plant than perennial rye grass, and it affords an earlier cutting, or bite, in the spring. Its florets (fig. 149) are invariably awned, as may be seen in the 'seed,' whilst those of perennial rye grass (fig. 148) very rarely carry awns. It is exclusively used for alternate husbandry, for which purpose it scarcely has an equal. On rich damp soils, that can be irrigated with liquid manure, Italian rye grass yields enormous crops, equally valuable both for soiling purposes (*see* p. 263) and for hay. It may be grown alone, or in association with cocksfoot, timothy, or broad clover. Dairy cows, grazed upon a temporary ley of Italian rye grass, give a great yield of milk, the flavour of the butter or cheese from which is excellent. This species is never found in old pastures.

Darnel (*Lolium temulentum*, L.) is an occasional weed of cornfields. It is distinguished from the other rye grasses by the circumstance that the solitary outer glume is longer (fig. 150) than the spikelet to which it belongs. Poisonous or intoxicating properties have been attributed to it.

Sweet grasses (*Glyceria*) occur naturally in water meadows, and in the Fen districts, and are seldom raised from seed. In the grass lands which they frequent, they constitute acceptable and palatable additions to the herbage, and are, as their name implies, distinctly sweet. The **floating sweet grass,** or floating manna grass (*Glyceria fluitans*, Br.), is a slender and graceful grass (fig. 151), liable in certain stages of growth to be mistaken for the spiked fescue (*Festuca loliacea*, fig. 132), which grows in association with it. The spikelets of the sweet grass are, however, longer, and contain a larger number of florets than is the case in spiked fescue. The reed

sweet grass (*Glyceria aquatica*, Sm.) is a far stouter plant (fig. 152), and shows a disposition to grow in the water-courses, and along their borders, rather than to spread itself over the meadow.

Sweet-scented vernal grass (*Anthoxanthum odoratum*, L.) is one of the earliest grasses to come into flower, and it may often be gathered in ear at the beginning of

FIG. 150.—DARNEL, *Lolium temulentum*, L.
With a single spikelet on the right, and enlarged floret on the left.

FIG. 151.—FLOATING SWEET GRASS, *Glyceria fluitans*, Br.
With a single spikelet on the right, and enlarged floret on the left.

April. It is a plant (fig. 153) of sparse habit, and, though it may be found in water-meadows, hayfields, pastures, copses, and hedgerows, it never constitutes more than an insignificant proportion of the total herbage. If the stalk of this grass is chewed, a sweet lavender-like odour, similar to that of new-mown hay, is perceived. This odour is given out in the process of drying, and to

it the agreeable scent of a freshly-mown hayfield is attributed. On the sheep-grazed Downs of the South of England, sweet vernal grows in association with sheep's fescue. The leaves of sweet vernal are flat, broad, and somewhat hairy, but the grass is not of coarse growth. Examine some of the florets and notice that they have only *two* stamens each, instead of three, as is the case with

FIG. 152.—REED SWEET GRASS, *Glyceria aquatica*, Sm. With enlarged spikelet on the left, and enlarged floret on the right.

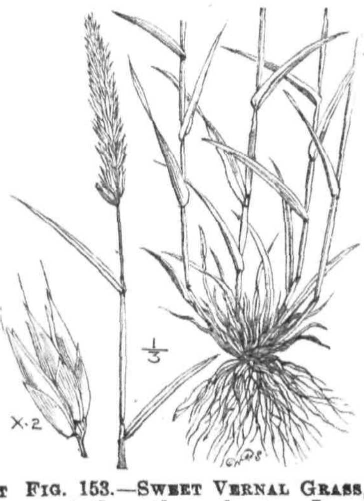


FIG. 153.—SWEET VERNAL GRASS, *Anthoxanthum odoratum*, L. With enlarged cluster of three spikelets on the left.

the florets of most species of grasses. The function of sweet vernal, both in pastures and in hay, is probably that of a condiment, as it is capable of imparting a flavour to the associated herbage. It grows in compact tufts, tillers freely, and continues to throw up its leaves until late in the autumn. The awns are hygroscopic, so that if some of the 'seeds' are placed upon the warm

moist palm of the hand, they will commence to writhe and wriggle about in a curious fashion.

Some of the seed of commerce comes from Central Germany, these being derived not from plants specially cultivated for the purpose, but gathered in glades and copses. It is therefore obtained only by long and fatiguing labour, and genuine samples are necessarily of high price. Derived from such sources, however, the seed is seldom pure, being usually mixed with seeds of other plants growing in the same localities, notably the seeds of woodrush (fig. 122), sheep's sorrel (fig. 113), and sheep's fescue (fig. 135).

In the district of North Luneberg, Prussia, there is frequently found growing in rye crops a bad annual weed, allied to sweet vernal, and known as **Puel's vernal grass** (*Anthoxanthum Puelii*). This forms such dense tufts that the scythe can scarcely cut them, and hence the mowing of the rye is rendered difficult. Large quantities of the seed of Puel's vernal grass are exported from Hamburg, and this worthless material finds its way into commerce as the seed of the true sweet vernal. On account of this origin, the seed of Puel's grass often contains the long-pointed grains of rye, as well as the long-awned seeds of the wind grass (*Apera Spica-venti*, L.), the seeds of cornflower, and of the annual knawel (fig. 154). It is not altogether easy to determine whether a solitary 'seed' is that of *Anthoxanthum odorātum* or of *A. Puelii*, but viewed in the bulk the latter is of a distinctly lighter brown colour than the former. Puel's grass is of little value. During its first year it permits scarcely any of the grasses near it to develop, whilst its dense tufts help to smother them. If, however, it is not allowed to shed its seed, it usually disappears in the second year. The seed of sweet vernal is sometimes adulterated with that (fig. 146) of the wavy hair grass (*Aira flexuosa*), but the latter is readily recognized by the lower half of its prominent basal awn being twisted.

FIG. 154.—SEED OF KNAWEL, *Scleranthus annuus*, L.

Timothy grass, or meadow catstail (*Phleum pratense*, L., fig. 155), derives its more familiar name from Timothy Hanson, by whom the cultivation of this grass was introduced from the United States of America about the middle of the eighteenth century. It is a native British species, and is relished by all classes of farm stock.

The only grass that timothy might be mistaken for is meadow foxtail, there being a general resemblance between the ears of these two species. A brief examination will serve to show, however, that they are really very different. The ear of timothy is green and rough, whereas that of foxtail is silvery grey and smooth; the florets of foxtail carry silky awns, those of timothy are awnless. Foxtail is an early grass, timothy a late one; the former will have gone to seed almost before the latter appears in ear, as timothy does not usually flower till July. The leaves have a greyish-green colour, and they are broader, and —especially when dried—stiffer, or more rigid, than those of foxtail; hence there is no difficulty in picking out the leaves of timothy from a sample of hay. Timothy is a perennial grass, with well-developed fibrous roots. Sometimes the base of the stem immediately above the root-fibres becomes bulbous, especially on poor land.

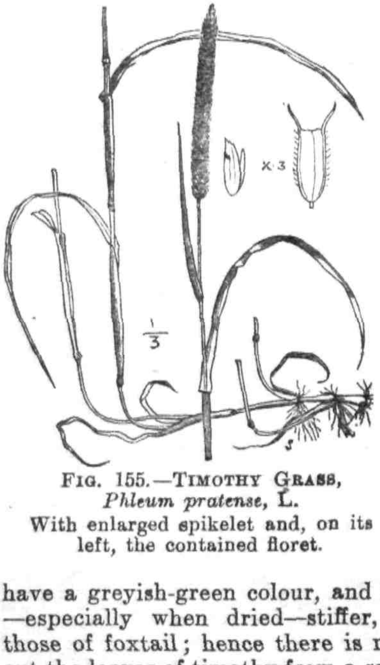


FIG. 155.—TIMOTHY GRASS, *Phleum pratense*, L.
With enlarged spikelet and, on its left, the contained floret.

Although timothy prefers a cool and even damp soil,

it yet resists drought very well, but yields in this case smaller produce. At the same time, it suffers less from the cold of winter than do several other cultivated grasses, and hence it is useful upon soils where other forage plants are liable to be killed by the winter's frosts. It succeeds best upon cold clays, and is specially valuable for reclaimed peaty soils. On dry soils, and upon shallow calcareous lands, it yields a very uncertain produce. Experiments prove that timothy responds freely to liberal manuring, and even a poor, light, sandy soil, when dressed with sulphate of potash, was found to give a much increased yield of this species.

Grown by itself, timothy produces a somewhat irregular sward of moderately close tufts. Associated with other grasses, or with clovers, it gives an abundant produce, for its hay is heavier than that of any other cultivated grass. It should be mown before flowering, otherwise its fibres become woody, and its hay is heavier and harder. The first cut is usually more productive than the second.

Whether grown alone or mixed with clover, timothy is more useful as green forage than as hay, because, even if the crop has been cut at the most desirable time, this species always hardens in drying.

The chief supplies of timothy seed are derived from North America, and, in part, from Eastern Germany and Austria. The American seed is usually much purer than the European, a circumstance no doubt due to the extensive cultivation of timothy as a crop by itself in North America. The raw European seed commonly contains from 10 to 20 per cent. of impurities, consisting of harmless particles of soil and vegetable fragments, and of the seeds of bad weeds.

The 'seed' of timothy consists of the grain, closely invested by the light drab-coloured flowering glume and pale. It is small, neat, and compact, and as there is no other seed which at all closely resembles it, adulterations or impurities in samples are easily detected. Timothy seed is used in making 'artificial' jams, to which it imparts the appearance of genuine strawberry 'seeds' (p. 177).

Various **weed grasses** have already been referred to, but it is necessary to notice certain others, such as the Brome Grasses, Couch Grass, Hair Grasses, Meadow Barley Grass, Quaking Grass, and Yorkshire Fog. They cannot be said to be wittingly cultivated by the farmer, but they frequently intrude, as uninvited guests, upon his domain.

The **Brome grasses,** native species of Bromus, are all weeds. They are handsome grasses, with elegant lance-shaped spikelets, each containing four or more awned florets. By far the most common is (fig. 156) the **soft brome grass** (*Bromus mollis*, L.), a too abundant constituent of the herbage of water meadows, hay-fields, and temporary leys, though but rarely found in old pastures. It sheds its seed in June, and is thereby enabled to maintain its position in the hay-field. Its spikelets are covered with short hair, which serves to distinguish it from the **smooth brome grass** (*B. racemosus*, L.) that frequently grows beside it. The **rye brome grass** (*B. secalinus*, L.) is a tall weed of cornfields, with a loose, somewhat drooping panicle. **Barren brome grass** (*B. sterilis*, L., fig. 157) is chiefly a roadside grass, and lurks beneath fences and hedgerows; its spikelets are darkish, flattened, and long-awned. **Hairy brome grass** (*B. asper*, Murr.), another denizen of the hedgerows, is the tallest of the bromes, often towering above the tops of the hedges. It has a large drooping panicle, with nodding spikelets, and the

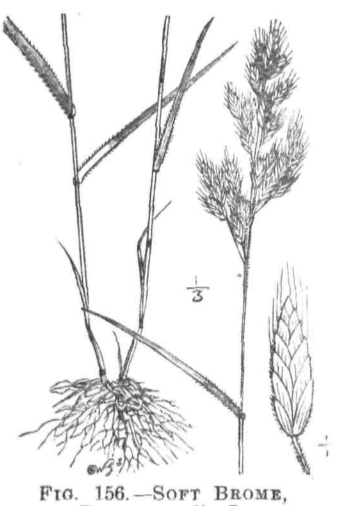


FIG. 156.—SOFT BROME, *Bromus mollis*, L.
With a single spikelet on the right.

stem is densely clothed with coarse hairs pointing downwards. **Upright brome grass** (*B. erectus*, Huds.) is a short-awned grass found in fields, but chiefly in waste places, upon chalky soils.

Couch grass (*Triticum repens*, L., fig. 158) is exclusively a weed of arable land, and its presence in permanent grass lands need only be looked for during the first year or two of their existence. Its vigorous underground stem (p. 152) grows with great rapidity, and sends forth roots and shoots at such frequent intervals that one plant is capable of speedily infesting a large area. The name 'couch' probably means 'quick' (*i.e.*, living), in reference to the vitality, and great difficulty of eradication, of this particularly noxious kind of grass. The labour of cleaning land from couch is chiefly directed to removing these troublesome underground stems—if they are merely cut up and left in the ground, each fragment will commence to grow as an independent plant. In Italy these stems, which are juicy, sweet, and nourishing, are collected, washed, and sold as food for horses. Couch grass in ear may often be found in the hedgerows of arable fields, where it serves as a great propagator of rust (p. 386). The spikelets have no stalks; they are (like those of wheat) set *broadside* on the stem, and each is furnished with two outer empty glumes. By the two last-named characters, an ear of couch grass is readily

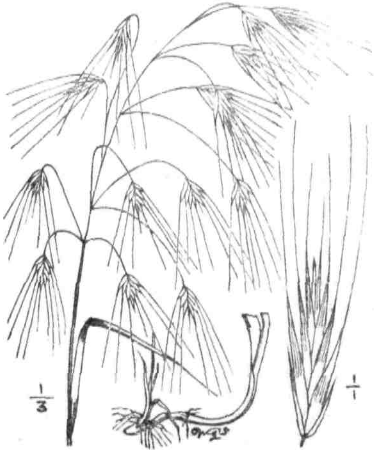


FIG. 157.—BARREN BROME, *Bromus sterilis*, L.
With a single spikelet on the right.

distinguished from an ear of rye grass (compare figs. 148 and 158). **Bearded wheat grass** (*T. caninum*, Huds.) is a long-awned ally of couch grass, from which it differs in not having a creeping underground stem. It occasionally appears in old pastures, but is not a cultivated grass.

The **Hair grasses** (*Aira*) make up a pretty group of plants, but they are all weeds. There are half-a-dozen native species, though, as a rule, only one is met with upon the farm—the **tufted hair grass,** or tussock grass (*Aira cæspitosa*, L., fig. 159). It grows chiefly in wet meadows and pastures, forming dark unsightly tufts or tussocks, termed in some districts 'bull faces' or 'bull pates.' Cattle seldom touch the hard, rough, flat leaves. Up to the time of flowering the panicle is exceedingly beautiful, owing to the brilliant silvery lustre of the purplish spikelets. At the time of flowering the panicle spreads wide open, and does not close again, the effective result of its compact appearance when young being thereby lost. Draining and manuring operate against *Aira cæspitosa*, and hand pulling, or chopping with an adze, is sometimes resorted to, the root being left to wither on the ground, or thrown upon the compost heap.

FIG. 158.—COUCH GRASS, *Triticum repens*, L.
With a single spikelet on the right.

The **wavy hair grass** (*A. flexuosa*, L.) is named in allusion to the wavy branches of its panicle. Its shining purplish or brownish spikelets may be seen in dry

woods and on sandy heaths, but seldom elsewhere. Its 'seed' is shown in fig. 146.

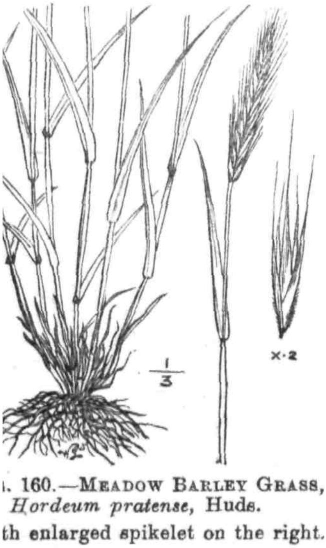
Meadow barley grass (*Hordeum pratense*, Huds.) has the appearance (fig. 160) of a diminutive plant of the cereal barley. It is not cultivated, as the long rough awns are unpleasant, and may prove injurious, to grazing animals. It occasionally occurs in hayfields and pastures, but is seldom abundant. The allied **wall barley**, or way bent (*H. murinum*, L.) is a weed of gravelly roadsides.

Quaking grass (*Briza media*, L.) is too well-known to need description. It grows usually on poor meadows and heaths, and throws up but little herbage. It seldom occurs in rich old pastures and generally disappears as a result of draining and liberal manuring. Its panicle, with the beautiful, purplish, nodding, boat-shaped spikelets on their slender stalks, is an exceedingly elegant object—it is easy to see in quaking grass what is meant by a 'spikelet.'

FIG. 159.—TUFTED HAIR GRASS.
Aira cæspitosa, L.
With enlarged spikelet on the right.

Yorkshire fog (*Holcus lanatus*, L., fig. 161) is a widely distributed weed grass. The whole plant has a delicate woolly covering, whence it is also known as meadow soft grass. This external coat, the flaccid character of the plant, and its bitter flavour combine to render it distasteful to stock. Its panicle, which remains closed up to the time of flowering,* is a pretty object, with its

various shades of colour, ranging from greenish to purplish. The panicle spreads out at the period of flowering, and as the seeds ripen it assumes a brown and withered appearance. Yorkshire fog is very common in water meadows and in inferior hayfields. It is less abundant in rich pastures, from which it is sometimes entirely absent. As it ripens its seeds early, hay containing much Yorkshire fog may be the means of disseminating this pest on arable sheep farms. The hay being fed in



ı. 160.—Meadow Barley Grass, *Hordeum pratense*, Huds.
th enlarged spikelet on the right.

Fig. 161.— Yorkshire Fo(
Holcus lanatus, L.
With enlarged spikelet on the ri

troughs to the sheep, the seeds of the Yorkshire fog fall out upon the ground, with the result that rows of *Holcus lanatus* spring up in the places where the troughs have stood. Yorkshire fog should be discouraged in favour of better grasses, and care should be exercised lest its 'seed' be inadvertently introduced, either as an adulterant, or as an impurity, in mixtures for sowing.

The closely allied **creeping soft grass** (*H. mollis*, L.) is much less common. It frequents hedgerows, copses,

and waste places, seldom intruding upon either the meadow or the pasture. Whilst *Holcus lanatus* is equally woolly all over, *H. mollis* is more woolly at the joints than on any other portions of the plant; by this means, and also by the awns (p. 226), the two species can be distinguished the one from the other.

THE CEREALS

Most of the forms of **wheat** in cultivation are varieties of *Triticum sativum*. The greater number of these are beardless, the remainder are bearded or awned. The soft beardless wheats are divisible into groups, according as the *ears* are white, reddish, or red; and the white and red varieties are again classed in accordance with either the smooth or downy character of the chaff. Of the smooth-eared wheats, whether white or red, the final division is determined by the colour of the *grain*—white on the one hand, red or yellow on the other.

White wheats, as a rule, require a better soil and climate, and are less robust than the red varieties. The quality of the grain is better, and they produce the best flour.

Red wheats, on the other hand, are more vigorous and generally yield better. They can generally be grown under less favourable circumstances as regards soil and climate.

Wheats of the better class, as regards both quantity and quality, are the produce of alluvial plains and fertile valleys. The wheat grain is the true fruit (p. 175) of the plant, and the flowering glume and pale do not harden on to it.

The term 'chested,' as applied to wheat, denotes the number of mature grains which are formed in each spikelet (p. 225). In three-chested wheat, for example, three florets in each spikelet produce ripe fruits; in four-chested wheat, four florets, and so on.

Barley (*Hordeum vulgare*) furnishes the varieties of two-rowed barley and six-rowed barley, the former distinguished as *H. distichum*, the latter as *H. hexastichum*.

It is a bearded cereal, the awns being long and rough, and assuming a beautiful purplish tinge at their free ends. The grain, as harvested, comprises the true fruit, closely invested by the light yellow flowering glume and pale. Peel these off a grain of barley, and the structure which remains is the equivalent of the wheat grain. When barley is subjected to a milling process whereby the outer fibrous coats of the grain are removed, the product is called *pearl barley*. Barley is specially noteworthy for the *flaggy*, or leafy, nature of its straw. **Bere** is the name of a coarse, hardy, four-rowed barley grown in Ireland and the North of Scotland.

Oats (*Avena sativa*), like barley, have the grain invested in the flowering glume and pale, though they adhere less closely, and are therefore more easily removed. The varieties commonly cultivated are: (1) the Common Oat, which has a spreading panicle, and (2) the Tartarian Oat, which is characterized by a one-sided panicle. By drying in a kiln or oven the separation of the coats of the grain is facilitated, and, after the husk has been removed in a mill, the groats or grits which remain are ground into *oatmeal*. The 'colour,' in the case of white and black oats respectively, is that of the dried flowering glume and pale.

Rye (*Secale cereale*) produces a grain or fruit similar to that of wheat, though less shapely, and without so well-defined a groove. It remains loose inside the flowering glume and pale, which do not adhere to it. There are a number of winter and summer varieties of rye, the former, the more commonly used, are sown in the autumn; the latter are sown in spring, and are quicker growing and less productive. Young rye, growing in the field, may be recognized by the purplish tinge of the stem, between the root and the first leaf.

Of the four cereals that have been enumerated, wheat is exclusively grown, and barley and oats are commonly grown in this country for the sake of their grain. In many districts, however, each of the two latter is sown in autumn, for spring feeding as a green crop, and in such cases is usually associated with vetches, or some other leguminous crop. The 'winter barley' thus culti-

vated is the six-rowed variety. Green wheat, on the other hand, is but very rarely fed on the ground. It seldom happens, except in the case of 'proud' wheat—that is, a crop which, owing to the effect of a mild open winter, has grown somewhat luxuriantly and unevenly. Such a crop may be fed off by sheep in early spring, in order that it may start uniformly upon its course of summer growth. The free propensity to tiller, which is characteristic of the wheat plant, enables it to grow vigorously after being grazed. Rye is nearly always grown as a green crop for spring feed, either alone or in association, and is seldom left to ripen its grain in this country.

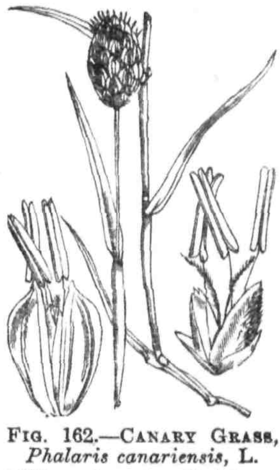


FIG. 162.—CANARY GRASS, *Phalaris canariensis*, L. With enlarged spikelet on the left, and enlarged floret on the right.

Maize, or Indian corn (*Zea mays*), and **sorghum** (*Sorghum saccharatum*) are gramineous plants, which are cultivated as cereal crops in warm countries. They are of robust growth, with stout succulent stems and broad flaggy leaves, and attain a considerable height. In the warmer parts of England they have been cultivated to a very limited extent in order to afford material for *green soiling*—that is, for cutting and feeding in the green state to cattle and sheep.

Canary seed is the product of **canary grass** (*Phalaris canariensis*, L., fig. 162), a native species which is very sparsely cultivated in a few districts in the south-east of England. It occupies the place of wheat in the rotation, but there is only an uncertain market for the 'seed,' which is used as food for cage birds. The plant is easily raised by sowing a few grains of 'canary seed,' and is sometimes found growing on rubbish heaps where bird-cages are cleaned out.

CHAPTER XIII.

WEEDS

A WEED has been defined as a plant growing in the wrong place, so that a potato-plant is a weed if growing in a cornfield, as is a wheat-plant in the kitchen garden. Weeds commonly usurp the place of the crop it is desired to grow, and cultivators have to devote much time and trouble to their suppression. As weeds are, in many cases, the *natural* produce of the soil on which the cultivator wishes to grow some special plant which would not spontaneously appear there, this circumstance tells in their favour. A fertile farm kept free of weeds is said to be in a *clean* condition, and it requires the highest skill of the farmer to maintain such a condition. Much of the elaborate working which arable land undergoes is directed to the extirpation or suppression of weeds, whilst, in the case of permanent grass land, other means have to be adopted.

Some of the commonest weeds have already been noticed in the preceding chapter, in connection with the cultivated plants to which they are most nearly allied. There remain certain other weed-plants which it is convenient here to specify in connection with the natural orders to which they belong.

RANUNCULACEÆ.—An order distinguished by having in each whorl of the flower the individual parts all distinct from each other; the sepals are not joined together, nor are the petals (which are absent in some species), nor are the stamens, nor the carpels. To this order belong the **buttercups** (species of *Ranunculus*), known also by such names as kingcup, crowfoot, spearwort. Buttercups grow as a rule on good land, and are amongst the commonest weeds of pastures. The **marsh marigold** (*Caltha palustris*) of water meadows, the **pheasant's-eye** (*Adonis autumnalis*) of cornfields, and the **wood anemone,** or windflower (*Anemone nemorosa*), are also members of the order. Excepting pheasant's-eye, which is an annual weed, the plants named are perennials.

PAPAVERACEÆ.—To this order belongs the **poppy** (*Papaver Rhœas*), one of the very few scarlet flowers native to this country. It is an annual plant, the fruit of which—known as the poppy head—contains an enormous number of seeds (fig. 163). The poppy is a most persistent weed of cornfields. Examine a specimen in bud and one in full flower, and notice that the calyx, consisting of two sepals, forms a kind of cap, which falls to the ground before the crumpled petals can expand. Observe the many-rayed sessile stigma resting upon the ovary; and cut across the ovary so as to bring into view the turned-in margins of the many carpellary leaves (*see* p. 176), which do not, however, meet at the centre. The **opium poppy** (*P. somniferum*) is allied to the field poppy, and, in India, opium is obtained by collecting the juice which exudes from the walls of the unripe 'heads,' when these are gashed with a small knife.

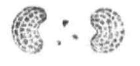


FIG. 163.—SEED OF POPPY, *Papaver Rhœas*, L.

FUMARIACEÆ.—A closely allied order to the preceding, but this has only six stamens in the flower, whilst the tips of the petals adhere together. Several species of **fumitory** (*Fumaria*) are very common annual weeds of arable land. They have much divided pale green leaves, and pale red (or white) corollas becoming darker at the tips.

GERANIACEÆ.—There are about a dozen native geraniums, or cranesbills, the latter name referring to the extent to which the dry fruit lengthens in the course of ripening. One of the commonest weeds in gateways, and under walls and hedgerows, is the strong-smelling pink-stemmed **Herb Robert** (*Geranium Robertianum*). Two or three other species, notably the **dove's-foot cranesbill** (*G. molle*) and the **cut-leaved cranesbill** (*G. dissectum*), occur upon arable land and in meadows, and their 'seed' (fig. 164) is sometimes introduced in unclean samples

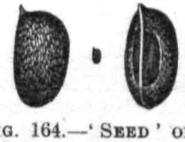


FIG. 164.—'SEED' OF SMALL-FLOWERED CRANESBILL, *Geranium pusillum*, L.

of clover seed. The geraniums that have been referred to are all annuals, and are small-flowered. The perennial blue **meadow cranesbill** (*G. pratense*), found in pastures, has much larger flowers.

RUBIACEÆ.—This is an order of plants made familiar by the bedstraws, with their weak straggling stems, linear leaves in circlets, and minute clustered flowers. The commonest is the plant variously termed **goose-grass, hariff,** and **cleavers** (*Galium Aparine*, fig. 165), with its knob-like fruits covered with small hooked bristles, whereby they adhere to clothes and to sheep's fleeces. It is an annual weed of rank growth in hedgerows. Rabbits eat it readily. On poor meadows and down land the **yellow bedstraw** (*G. verum*), with numerous small, bright yellow flowers, is a common perennial weed. There are about ten native species of bedstraw (fig. 166). The **field madder,** or **blue sherardia** (*Sherardia arvensis*), is a small lilac-flowered annual weed common in cornfields.

FIG. 165.—GOOSE-GRASS. *Galium Aparine*, L. With enlarged flower, pistil, and fruit.

FIG. 166.—SEED OF WHITE BEDSTRAW, *Galium Mollugo*, L.

CONVOLVULACEÆ.—The **lesser bindweed** (*Convolvulus arvensis*), with its twining stem, and its pinkish-white funnel-shaped aromatic flowers frequented by insects, is a troublesome pest of cornfields and potato beds. The manner in which it binds together the potato haulms renders it difficult to dig the crop. The **larger bindweed** (*C. sepium*), with its much bigger white flowers, is

confined to hedgerows and other fences. Both are perennials.

Dodders are parasitic flowering plants (fig. 167) allied to the bindweeds. Their seeds germinate in the ground, and, in the case of the clover dodder (*Cuscuta Trifolii*), the young shoot, coming in contact with the stem of a clover plant, develops *suckers* or *haustoria*. As growth progresses the dodder produces more haustoria, with the result that it becomes entirely parasitic upon the clover plant, and, whilst it appropriates the nutriment which the clover has elaborated for its own growth, it gradually strangles its 'host.' This unequal struggle terminates in the death of the clover plant, and sometimes in a clover field numbers of bare patches may be seen where the crop has been destroyed by dodder. In such cases the clover should be fed off by sheep

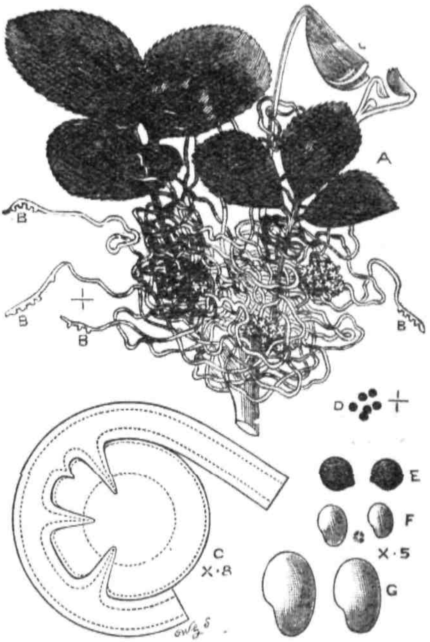


FIG. 167.—CLOVER DODDER.
Cuscuta Trifolii, Bab.
A, clover plants infested with dodder.
B, suckers or haustoria of dodder.
C, section of clover stem, showing attachment of dodder suckers.
D, dodder seed, natural size.
E, dodder seed; F, white clover seed; G. red clover seed — magnified five diameters.

at once, the field should be ploughed up, and clover should not be grown again upon the same land for a number of years, in order that the dodder seed in the soil may have time to die. Clover seed should always be examined, and, if it contains any of the small brownish wrinkled seeds of dodder, it should on no account be sown. To employ such seed is an act of great folly.

Clover dodder has a yellowish-pink straggling stem, with no leaves and with numerous clusters of small flowers. The plant grows in the fashion of a heap, the narrow stems alone being exposed to outward view, and the clusters of flowers turned towards the ground. Pulled away by hand, the mass is felt to be rather sticky. The plant has a faint aromatic odour.

Other species of dodder attack the flax, and some are parasitic upon the stinging-nettle. Heather is another victim, and pretty examples of dodder-infested heather are to be seen in July and August upon moorlands and mountains.

SCROPHULARINEÆ. — The **snapdragon** (*Antirrhinum majus*), the **foxglove** (*Digitalis purpurea*), and the **musk plant** (*Mimulus moschatus*) of cottage windows, are examples of this order. There are usually four stamens, two being longer than the others, whilst the fruit is a two-chambered capsule, and the corolla is in most cases two-lipped. The **toad-flax** (*Linaria vulgaris*) is a familiar weed with a yellow and white flower, hence called 'eggs-and-butter.' Various weeds of the order possess roots which are partly parasitic upon the roots of grasses and clovers. Such are the **red bartsia** (*Bartsia Odontites*), common in cornfields; the **yellow rattle** (*Rhinanthus Crista-galli*), growing in meadows; the **eye-bright** (*Euphrasia officinalis*), **lousewort** (*Pedicularis sylvatica*), and **cow-wheat** (*Melampyrum pratense*). The **figwort** (*Scrophularia nodosa*), which is poisonous, grows in damp meadows, beside ditches; and the tall yellow-flowered **mullein** (*Verbascum Thapsus*), with its *five*-stamened flowers and large downy leaves, frequents the hedge-rows. Perhaps the most generally distributed plants of the order are the small blue-flowered **speedwells**

(species of *Veronica*, fig. 168), which are often abundant upon arable land and in waste places—in some country districts the flowers are called 'bird's eyes.' The four petals are unequal in size, and there are only *two* stamens.

OROBANCHACEÆ.—This order is closely allied to the Scrophularineæ. It is made up chiefly of the various kinds of parasitic plants known by the general name of **broom-rape** (*Orobanche*, fig. 169). The most familiar form is that which attacks clover.

FIG. 168.—GERMANDER SPEEDWELL, *Veronica Chamædrys*, L. With single flower on larger scale.

FIG. 169.—LESSER BROOM-RAPE, *Orobanche minor*, L. With parts of flower on larger scale.

During July and August there may be seen, in aftermath clover, especially upon chalk soils, the thick fleshy yellowish-brown upright stems, 6 to 10 inches high, of broom-rape. The leaves of the parasite are reduced to mere pointed scales, devoid of chlorophyll, whilst towards the free end of the stem are numbers of dingy gaping flowers. The plants are easily pulled up by hand, when the underground portion of the stem is seen to possess a bulb-like swelling, from the base of which a few straggling roots proceed. These are

parasitic on the roots of the clover plants. Hand-pulling is the best remedy against broom-rape, and, where a field is badly attacked, clover should not be grown upon the land again for a number of years.

Various other plants are liable to the attack of species of broom-rape, the name of which appears to relate to the fact that the leguminous plant, broom, is one that has its nutriment thus stolen.

PRIMULACEÆ.—The characters of this order are well seen in the **cowslip** (*Primula veris*) and **primrose** (*P. vulgaris*). The **scarlet pimpernel** (*Anagallis arvensis*) shares with the common poppy the rare distinction, in the British flora, of possessing scarlet petals. This is an abundant annual weed of arable land. It has a prostrate stem, with sessile oval leaves having black dots on their under faces. Notice the fruit, an elegant spherical capsule, opening by a lid, and containing numerous seeds (fig. 170) attached to a central peg or axis (free central placentation). As the petals close up on the approach of rain, the plant is also called the poor man's weather glass, or shepherd's weather glass.

FIG. 170.—SEED OF SCARLET PIMPERNEL, *Anagallis arvensis*, L.

PLANTAGINEÆ.—To this order belongs the **ribgrass, ribwort,** or **plantain** (*Plantago lanceolata*), sufficiently well known by its flat rosette of lanceolated leaves with five prominent ribs. The inflorescence is a spike. The densely aggregated flowers are somewhat parchmenty (scarious), and the seeds, which look like small polished date-stones (figs. 171-2), are often seen in samples of clover seed. The close-lying leaves of the plantain, like those of the daisy, frequently disfigure lawns, where the plant should be spudded up, and sulphate of ammonia used. On loose sandy soils, and on railway embankments the plantain is sometimes sown for the binding effect of its roots.

The **greater plantain** (*P. major*), with larger leaves, occurs in meadows and pastures, and on roadsides. Its spikes elongate after flowering, and are often fed to

cage-birds. The **hoary plantain** (*P. media*) has downy leaves, which spread out flat on the ground, and are ovate in shape. The species is found in close dry pastures and on lawns.

JUNCACEÆ.—The rushes and wood rushes are members of this order, and are referred to on page 227.

CYPERACEÆ.—This is the extensive order to which the sedges belong. They are described on page 228.

Weeds must be considered in their relations both to plant food and to soil moisture. When they occur *amongst growing crops*—as charlock in the turnip-field, or poppies in the corn—they take to themselves the food which the husbandman desires should contribute to the growth of the crop. They are thus robbers of

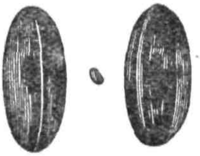


FIG. 171.—SEED OF RIBWORT, *Plantago lanceolata*, L.

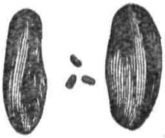


FIG. 172.—SEED OF HOARY PLANTAIN, *Plantago media*, L.

crop-food, as equally are the undesirable species that find their way into meadows and pastures. Field experiments on various crops have shown that clean plots yield from 40 to 50 per cent. more than unweeded ones.

Nevertheless weeds are **not always harmful.** After harvest or during a period of bare fallow, when no cultivated crop occupies the land, weeds spring up in great abundance, and in such circumstances they do useful work in retaining in the soil the nitrogen which might otherwise be washed out of it in the drainage waters (*see* p. 33). In thus intercepting the nitrogen they play the part of a green crop, and, when they are ploughed into the land, the nitrogen, in the course of time, becomes again available as plant-food. A specially sown green crop would, no doubt, answer the purpose better, and care must always be taken to bury

the weeds before they are sufficiently advanced to shed their seeds upon the ground. An old saying runs, 'One year's seeding is seven years' weeding.' Single plants of some weeds can produce an astonishing number of seeds—*e.g.*, ribwort plantain, 2,500 to 15,000; charlock, up to 4,000; and groundsel, up to 20,000.

When weeds dispute the possession of the land with a growing crop, they are capable at certain seasons of seriously affecting **the supply of moisture.** It has already been explained that land under crop gives up more moisture than adjoining bare land. Weeds spring up in a very short time in summer, they grow rapidly, and they help to suck the soil dry. Then it is that those crops which cannot be hoed begin to suffer, and the farmer learns how difficult it is to raise a satisfactory crop upon a foul seed-bed. Weeds also compete with crops for **air, light,** and **heat;** while many of them either shelter or serve as hosts for **insect** and **fungoid pests.** A good example of the last point is afforded by charlock, that harbours turnip 'fly' during the early summer, besides which its roots may be infected by turnip gall-weevil and the germs of 'finger-and-toe' disease. It may be added that some weeds are **poisonous,** and others—*e.g.*, wild onion—injuriously **affect the flavour of milk.**

Preventive Measures.—The importance of **preventing weeds from seeding** has already been emphasized, and the desirability of using **clean seed** is sufficiently obvious. It has been calculated that if a mixture of grass and clover seeds contains only one per cent. of dock, this means a possibility of ten or more dock plants per square yard of the field sown with the mixture. **Hedges and ditches,** which shelter many weeds, should be kept in good order, and **screenings** used as food for stock should be thoroughly ground, so that the weed seeds they contain are destroyed.

Good cultivation, associated with a **sound rotation,** which gives opportunities of keeping the land clean, is probably the best preventive measure of all. In some cases the growth of dense leguminous crops, such as lucerne, prevents weeds from coming to maturity.

Remedial Measures.—In the perpetual war which it is necessary to wage against weeds, the mode of procedure is determined partly by the length of life of the weeds themselves, and partly by the nature of the crop. On arable land, where the crop permits of it, the hoe is kept constantly at work. It is specially important that **surface weeds,** which are mostly those of annual species, should be cut out, and left to wither upon the ground, before they begin to form their seed. One of the advantages of a root-crop, in a rotation, is that it thus permits of a periodical crusade against annual weeds, such field pests as poppy, fumitory, charlock, and others being thereby checked. Perennial weeds are less easily subdued, and plants like dock, knapweed, and garlic have frequently to be pulled up by hand, a class of work that can still be undertaken when the crop has so far advanced that hoeing is no longer practicable. As a rule, perennial weeds develop stouter, longer roots than those of only annual duration; and the hoe frequently fails to penetrate deeply enough to destroy the buds at the crown of the root. Where couch-grass and docks abound upon arable land, *they should be vigorously attacked with the hand-fork* directly after harvest.

In the case of permanent grass land, generous treatment in the matter of manuring will, by encouraging the robust growth of the desirable plants, promote the suppression of weeds. In old grass land, most of the weeds are perennials, the decreasing quantity of annual weeds in newly laid down land being one of the indications of success. The weeds of common occurrence upon grass land have already been described in the last chapter. In the case of thistles and knapweeds, docks, and sorrels, the spud should be freely used, and the whole plant bodily removed. Thistles should be cut when they come into flower, otherwise they are capable of spreading rapidly by means of the seeds contained in the thistledown, which is so easily carried away upon the breeze. In some countries it is an offence, punishable by law, to permit such weeds as thistles and charlock to ripen their seed.

Special **chemical treatment** has gradually been coming into favour as a means of killing certain weeds. The best example is the process of **spraying for charlock** with 4 per cent. solution of **copper sulphate** or 15 per cent. solution of **iron sulphate,** used at the rate of not more than 40 gallons per acre, and applied by means of a spraying machine. The same treatment applies to wild radish.

Sulphate of ammonia is a valuable dressing for stimulating the growth of grasses, and getting rid of weeds. Lawn sands, often of great value in the extirpation of daisies, dandelions, and plantains, chiefly consist of a mixture of sand and sulphate of ammonia.

Common salt, for application to nettles, and as a general dressing for grass, has proved useful in some cases, while **carbolic acid** (1 pint of acid to 4 pints of water), to the extent of 8 gallons per square rod, destroys wild onion and some other weeds.

Sodium arsenite is the effective ingredient of many 'weed killers,' but it is so exceedingly poisonous that its use is not to be recommended.

CHAPTER XIV.

SELECTION OF SEEDS

In the selection of seeds for sowing the main conditions for the purchaser to secure are (1) adequate germinating capacity, (2) identity to species, (3) freedom from impurities.

The **germinating capacity** of a sample of seed is easily ascertained by following the method already described (p. 127) for germinating the bean seed, counting out 100 seeds for the purpose. Small seeds are most conveniently germinated between two pieces of damp blotting paper, which are placed on a piece of felt saturated with water, this again being put on a plate, so that the supply of moisture can easily be maintained.

The following table (from Harold C. Long) shows what may be expected in satisfactory samples:—

TABLE XXI.—USUAL PURITY AND GERMINATING CAPACITY OF FARM SEEDS.

Kind of Seed.	Purity.	Germinating Capacity.	Average Time of Germination.*
	Per cent.	Per cent.	Days.
Cabbage...	96 to 98	90 to 95	2
Swede	96 to 98	90 to 95	2
White turnip	96 to 98	90 to 95	2
Black mustard	96 to 98	85 to 90	2
White mustard	98	95	2
Lucerne	96 to 98	92 to 98	3
Yellow trefoil	96 to 98	90 to 95	3
Crimson clover	90 to 95	90 to 95	3
Red clover	98	95 to 98	3
Alsike clover	98	95 to 98	3
White clover	98	95 to 98	3
Kidney vetch	95	95 to 98	3
Bird's-foot clover ...	98	95	3
Sainfoin	98 to 100	90	4 to 6
Carrot	95	70	6
Parsnip	95	60	6
Mangel wurzel (fruits)	98 to 100	125	6
Buckwheat	98 to 100	85	4
Sweet vernal grass ...	96	60	5
Meadow foxtail ...	96	75 to 80	6
Timothy	98	90	4
Golden oat-grass ...	98	60 to 70	5
Tall oat-grass	98	90	5
Crested dogstail ...	96	80	5
Cocksfoot	98	80 to 90	7
Smooth-stalked meadow-grass	98	60 to 70	7
Rough-stalked meadow-grass	98	60 to 70	7
Meadow fescue... ...	98	90 to 95	5
Hard fescue	96	70 to 80	7
Sheep's fescue	96	70 to 80	7
Perennial rye-grass ...	98 to 100	95	5
Italian rye-grass ...	98 to 100	95	5

* These figures refer to 'energy of germination,' or the speed at which high-class samples germinate. In order to complete a test of germinating capacity, however, up to 10 days should be allowed in the case of the first 13 species in the list, and up to 14 days for the rest, except the meadow-grasses, for which a month should be allowed.

Very brief experience will show that, even in the same sample, the time occupied in germinating will vary considerably amongst individual seeds, and this is markedly the case with clovers. This is partly due to the coat or covering being thicker and tougher upon some of the seeds than upon others, and therefore bursting less easily. It may also be due to difference of age, old seed not germinating so readily as young seed: whilst as age advances the contained germ dies, and a dead seed will never germinate.

In seeking to express, by a number, the germinating capacity of seed, care must be taken to secure a representative sample. At the same time anything that is not obviously a seed should not be employed in estimating germinations, as the question of impurity affects a separate valuation of the sample.

Identity to species—that is, a sample actually being that which it is asserted to be—sometimes requires expert knowledge for its determination. This is especially the case, as has been seen, with certain grass seeds, and it has sometimes happened that an inferior seed has been substituted in bulk for that of a superior and more costly species. In some cases it is almost impossible to distinguish between the seeds of different kinds of plants—as between those of rape and swede, or between those of broad clover and true cow grass (*see* pp. 193-4). It is often desirable to learn something of the **stock** from which a sample is derived; thus, it may happen that a sample of swede seed germinating 100 per cent. may be greatly inferior to another germinating only 80 per cent., because the former is of a wild bastard stock running to fangs and tops.

The **impurities** in samples of seed may be classed as injurious and harmless. The latter consist of dead seeds, fragments of plants, bits of stone, etc. They do not influence the essential character of the sample, and they do no harm upon the land. Still, it is obvious that if a sample of seed contains, say, 10 per cent. of its weight of such non-living impurities, then twenty pounds of the seed, as purchased, will only furnish

eighteen pounds of genuine seed, whilst the two pounds of rubbish are paid for at the same rate as the good seed.

The injurious impurities may, according to their nature, detract very seriously from the value of a sample. They may even render it in the highest degree unwise to use the seed for the purposes of sowing. The impurities belonging to this class are usually living seeds of weeds and parasitic plants. In the section on Grasses (pp. 221 to 261) many such impurities are noticed. Grass seed sometimes contains the purplish-black spurs of the fungus parasite, ergot (*see* p. 393), and such seed should always be rejected. Clover seeds are liable to contain the seeds of the parasitic flowering plant, broom-rape (*see* p. 269), and of the still more objectionable parasitic flowering plant, dodder (p. 267). Such seeds should never be sown. The seed of plantain or ribgrass (p. 271) is a common and easily recognized impurity in samples of clover seed; cranesbill 'seed' (fig. 265) in samples of clover seed is less promptly detected. Additional weed seeds frequently found in samples of clover and other agricultural seeds include those of the bladder campion (nat. ord. Caryophyllaceæ), dove's-foot cranesbill and cut-leaved cranesbill (Geraniaceæ), hedge parsley and wild carrot (Umbelliferæ), goose-grass and blue Sherardia (Rubiaceæ), scentless Mayweed, sharp-fringed sow thistle, and nipplewort (Compositæ).

Real Value.—This is the combined percentages of purity and germination, and is obtained by multiplying these percentages and dividing by 100; thus in a sample of meadow fescue having 88 per cent. purity and 95 per cent. germination, 88 multiplied by 95 gives 8,360, and this divided by 100 gives 83·6, the Real Value.

Collections of Seeds.—The student will find it useful to make a list of the weeds the seeds of which are named (pp. 229 to 256) as impurities of grass seed. The plants producing these respective seeds should be identified in the field; and, in the summer and autumn, samples of their seeds should be collected, and put into small bottles or boxes, correctly labelled. In the same way, make a collection of pure grass seeds and of pure

clover seeds. They will all be useful for purposes of reference and comparison, whilst, by examining the samples occasionally with a magnifier, the distinctive characters of each seed will be learnt; knowledge of this kind is always valuable. Take care that each sample is well dried in the sun before it is corked up, or it will soon begin to decay. Seeds of buttercup, shepherd's purse, chickweed, ragged Robin, corn cockle, cranesbill, wild carrot, corn bluebottle, self-heal, dock, sorrel, knot-grass, soft brome, Yorkshire fog, and of other notorious weeds, may thus be collected in the course of a season. Their characters learnt in this way in the field are never forgotten, and more useful information is thus pleasantly obtained than could be acquired by years of mere reading.

It may be useful, however, to warn the student that the appearance of a seed—of wild carrot, for example—as ripened in the field, may not bear much resemblance to the same seed as it occurs in a sample of clover seed. The friction induced during the several processes involved in the cleaning of the clover seed modifies the external characters not only of wild carrot, but of a number of other weed seeds. Allowance should be made for this alteration in appearance.

In purchasing seed it is well to remember that **bad seed is dear at any price,** and that clean genuine samples are usually worth the extra money asked for them. Read, however, what is said about the cleaning of land and preparation of the seed bed on pp. 283-5.

No hard and fast rules can be given concerning the **depth** at which the various kinds of seeds should be sown. It may be stated in a general way, however, that the depth of sowing should vary as the size of the seed, so that the larger the seed the greater—within limits—should be the depth at which it is sown. On the other hand, very small seed requires very shallow sowing.

CHAPTER XV.

GRASS LAND AND ITS MANAGEMENT

Grass land, either temporary or permanent, plays a very important part in the economy of the farm. During the latter part of the nineteenth century, owing to the depression in arable farming following on the fall in the price of wheat and the enhanced cost of labour, there was a steady increase in the area under permanent grass in Great Britain, and this has continued, though to a less degree, during the first decade of the twentieth century.

In 1913 there were some 17,571,360 acres under permanent grass in Great Britain, of which more than a quarter was cut for hay. The returns of the Board of Agriculture further show that the area of permanent grass cut for hay each year alone is greater than the acreage of any other crop in Great Britain.

Considering these facts there is every inducement for skilful management to be bestowed upon the grass land in this country; but unfortunately this is often not the case, and while the arable land is liberally treated the grass land is allowed to take care of itself, the principle that 'what is taken out should be put back' being largely neglected.

Grass land is either **temporary** or **permanent.** In the former case, often spoken of as a 'temporary ley,' seeds of grasses and clovers are sown, and after a period of variable length, the land is ploughed up again. Permanent pasture land, on the other hand, remains continuously under grass; it may either have been grass land from time immemorial, or it may have originated recently in the sowing of 'seeds.'

Permanent grass land is generally referred to as *pasture* or *meadow*.

The term **pasture** may be conveniently applied to grass that is grazed, but never mown, as certain of the old ox-pastures in some of our best grazing districts. The term **meadow,** on the other hand, is used to indicate grass

land which is cut for hay each year, although at certain periods it may be grazed. In some counties, however, as Gloucestershire, it is the custom to mow and graze in alternate years, although this seems to lead in many cases to an impoverishment of the grass land, owing to neglect to make a sufficient return in the form of manure for the hay crops that are removed. The phrase *permanent pasture* is often used very loosely to denote any grass land that has not been broken up for a number of years, and thus to include old meadows or hayfields. As much confusion thereby arises, it is better to restrict the term pasture to land used exclusively for grazing.

The distinction is important because there is considerable difference between pastures and meadows as thus defined. This difference extends not only to the quantity and quality of the herbage, and to the relative proportions of the component species, but also to the 'condition' of the soil. In grazing, the animals feed upon the pasture, and return to the land much of what they take from it. If they are at the same time receiving additional food their effect upon the land is correspondingly greater. Not only do animals thus manure the land, but they improve its texture by their constant treading. In the case of a regularly mown meadow the hay is carried off the land, and may even be sent off the farm altogether and consumed elsewhere. In thus giving up its annual crop of hay the meadow land is impoverished to a far greater extent than the pasture land, and this impoverishment has to be met by dressing the land with natural or artificial manures. If a grass field be divided into two, and, whilst the one part is continuously grazed, the other part is regularly mown, it will be found that in time the herbage of the pastured land will differ very materially from that of the meadowed land. The plants which thrive best under the treading and grazing of animals are not exclusively the same species as flourish most readily under the scythe.

Conclusions to be drawn from recent experiments tend to show that better results are obtained in the management of grass land when it is kept for one special

purpose, either for grazing stock or mowing for hay, in the latter case the aftermath only being fed, than by grazing and mowing in alternate years. In this way the fullest development of the grasses and clovers which are best suited to haying and grazing respectively are obtained.

WATER MEADOWS

Water meadows are grass lands which, by a convenient arrangement of water courses and sluices, can be periodically 'flooded' or 'drowned.' They are usually situated near a river or stream, which supplies the water for purposes of irrigation.

There are two systems commonly employed in laying out water meadows, viz. :—

(1) The Ridge and Furrow, or Bedwork System.

(2) The Catchwork System.

The **ridge-and-furrow system** is generally adopted where the land is fairly flat. The land is laid out in ridges about half a chain in width, along the top of which run 'feeding channels' or 'floats' for conveying the water on to the land from the main carrier, which brings it from the stream. Along the furrows between the lands are a second series of channels, which act as drains for collecting the water after it has flowed over the ridges, and conducting it by means of the main drain back to the stream. The floats being at a higher level than the drains, when the land is flooded a steady stream of water trickles amongst the herbage from a feeding channel to a draining channel.

The general arrangement of a water meadow on the ridge-and-furrow system is shown in the diagram.

The feeding channels vary in width and depth according to circumstances, being wider at the end where they join the main feeder and narrowing towards their extremity. With the draining channels this is reversed, their widest end being that at which they join the main drain. The principal drawback to this system is the expense incurred in laying out the land in the first instance, which is often considerable. The other kind

of water meadow, on the **catchwork system,** is specially adapted to grass lands that lie on a steep declivity, running away from a stream, and examples are to be seen in Somerset and Devonshire.

A series of parallel channels are cut at intervals running across the slope, and water is introduced into the first of these till it gradually overflows and runs steadily down the surface of the slope, accumulating in the second channel, which is again allowed to overflow, and the process is repeated. This goes on till the water,

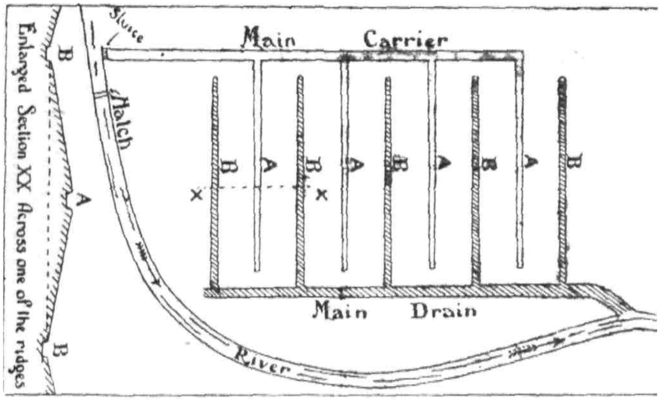


FIG. 173.—DIAGRAM SHOWING SCHEME OF IRRIGATION IN WATER MEADOW.

AAA, Ridges; BBB, Furrows.

having evenly saturated the surface, collects in a drain at the bottom of the field, and is thence conveyed to a stream.

This system is generally a very cheap one to lay out where the conditions are suitable.

The **method of management** consists in flooding the meadows continuously at intervals throughout the winter, the water being allowed to remain on them from three to fourteen days at each operation. This alternate flooding and drying forces an early growth of grass,

and goes on from October to March, when the 'meads' remain unflooded for a month or more, in order that they may be fed off by ewes and lambs. Periodical floodings are then resorted to till June, during which month the meadows are dried for mowing. Towards the end of July they are again flooded, and afterwards grazed by horses and cattle till October.

In laying out any system of irrigation the first thing to be considered is the water supply. The best water for the purpose is that supplied by a clear running stream free from iron and other soluble matters likely to damage the grass. A trout-stream is generally considered suitable for the purpose. When the meadows are flooded the water should be running all the time, and not allowed to become stagnant. Water should not be turned on during a frost; but if a frost comes on when the water is running it should be allowed to continue to run, so as to protect the ground, as the temperature of running water is higher and more constant than that of the air.

The chief advantage of a water meadow is to be seen in a droughty summer, when, owing to the constant supply of moisture, a crop of grass can be relied upon. In winter, also, the running water increases the temperature of the soil, so that the growth of the grass is hastened, and an early bite obtained in spring. Further, the water acts as a carrier of plant food, and fertilizing material is brought on to the soil in solution and suspension, while air at the same time is allowed to enter and produce its sweetening effect on the body of the soil.

LAYING DOWN LAND TO GRASS

In laying land down to grass it is essential, in order to ensure success, that the land should be clean and in good condition, and the seeds pure. It is useless to secure one of these conditions without the other, for it would be as futile to sow pure seeds upon a foul seed-bed and land in poor condition as to prepare a proper

seed-bed for the reception of unclean seed. If the object is to obtain a pasture in the shortest possible time, it will be necessary, besides selecting a mixture suitable for the purpose we have in view, to use skill in the preparation of the soil, and to be liberal in the after treatment of the young pasture.

As regards soils, the stronger ones which are cool and moist are best suited to the growth of grass; whereas the lighter sands and gravels in the drier districts do not form a turf so readily.

The most effective way to **clean the land** is to thoroughly work it during a bare fallow in summer. when it will be ready for seeding in the following spring. As, however, bare fallowing is an expensive operation, it is usual to take a root crop, which offers the additional advantage that it may be well dressed with farmyard manure, whilst the condition of the soil is further improved when turnips are fed upon the land in autumn to sheep, which at the same time are consuming cake. As soon as the land is free it is subjected to a deep ploughing, followed speedily by another ploughing, and the land is then laid up through the winter. In the North of England, however, deep ploughing is not resorted to after a green crop has been fed off by sheep, for, although a second ploughing may bring the sheep-droppings again to the surface, this second ploughing cannot always be accomplished at once. As soon in the early spring as it is practicable to resume operations the harrow and roller are set to work, and are kept going till a fine firm level seed-bed is produced.

The object should be to obtain a deep mellow **tilth,** but very firm; and on the top of this a very shallow and fine **seed-bed** should be formed, so that the small seeds are not buried too deeply. A good plant of seeds is often seen on the headlands, which have been well trampled by the horses in turning, when the rest of the field is very patchy. The seeds may be sown alone or with a corn crop. If the pasture is wanted at the earliest moment the grass seeds are best sown without a crop. In this case it is advisable as soon as the grass gets ahead

to mow it at intervals, which will tend to strengthen the young grass and cause it to tiller out.

Sowing with a crop, however, is the usual method, as it is more economical in ordinary practice. The corn, also, acts as a shade and nurse in a hot summer, and helps to check the growth of weeds. The seeds are thus usually sown with a thin seeding of wheat, barley, or oats, and may be put in either at the same time as the corn or when the latter is a little way above the ground. In some districts a preference is given to autumn-sown wheat as a nursing crop for young seeds, where it is thought to be less liable to 'lodge' than oats or barley; and in this case there is also the advantage of a solid soil, with an inch of fine mould on the surface as a seed-bed.

The spring, from the end of March to the beginning of May, is the best time for sowing grass seeds. Early sowing is to be preferred, providing the ground is sufficiently dry. Autumn sowing is sometimes adopted on certain soils, but care must be taken to sow early, in order that the young plants may be sufficiently strong before winter, and thus be able to withstand the attacks of frost.

Some skill is required in **sowing mixtures of grass seeds,** as, on account of the different sizes and weights of the various species, irregularity may result. A still day is preferable, as the lighter grass seeds are easily carried by the wind. The use of the seed-barrow, which delivers the seed near to the ground, is more reliable than broadcasting by hand. To secure uniformity of sowing, it is a good plan to wheel in the grass seeds alone in one direction, and then the clover seeds by themselves in a direction at right angles to the former.

To prepare the surface of the land for the seed, the land is generally rolled first. After sowing, the seeds should be covered by lightly 'brushing' or harrowing, and then the ground should be firmly rolled down in two directions.

Drilling grass seeds with the seed-drill is now sometimes adopted, especially on light soils, and has certain

advantages in a dry season; but it is important that the ground should be rolled down tightly afterwards.

The skilful **after management** will determine to a large extent the success of a young pasture. The chief point during the first few years is to get the long-lived grasses predominating, and to encourage the development of an even sole or bottom to the pasture. This can be done to a certain extent by keeping down the top grasses and allowing nothing to run to seed so as to weaken the growing plants.

As soon as the corn crop is off it is sometimes found that the young herbage is very forward, especially after a damp summer. It may, therefore, be necessary to top it with a mowing machine, or cattle may be turned on, but it is advisable to keep sheep off a young permanent pasture for the first two seasons. It is a good plan to give a newly laid-down turf a dressing of farmyard manure or compost during the winter after the corn crop is removed, or if this is not convenient, an application of artificial manure may be used to stimulate the growth of the plants. Such an artificial mixture should be a complete one, and contain the three chief plant-foods, nitrogen, phosphoric acid, and potash, and may consist of:—

Superphosphate	3 cwt.
Kainit	2 ,,
Guano	1 ,,

or with soils well supplied with potash, the following may be used:—

Steamed bone flour	5 cwt.
Nitrate of soda or sulphate of ammonia ...	1 ,,

These mixtures should be used at the rate of 6 cwt. to the acre.

It is a good practice to mow a permanent pasture the first year after sowing; but care should be taken to make a liberal return in the form of manure to compensate for what has been taken off.

Grazing the land with bullocks which are receiving an additional allowance of food in the form of cake

and corn will be found a very beneficial treatment as soon as the pasture is established. Feeding beasts take very little out of their food, and when they are receiving cake the fertility of the soil actually increases. Young and milking stock, on the other hand, are not so suitable for grazing on pastures while they are forming, as they make much greater demands on the land than feeding stock.

MIXTURES FOR SOWING LAND DOWN TO GRASS

Attention has already been drawn to the necessity for using clean mixtures when sowing down land to grass. The old custom of mixing the sweepings of the hay loft with a few purchased seeds to make up a mixture for sowing was often responsible for distributing weeds and worthless grasses over the farm. Although ready-made seed mixtures, adapted for any purpose, can now be obtained from most of the leading firms of seedsmen, still it is to the farmer's advantage to know something of the common grasses and clovers, and the proportions in which they should be mixed to suit his particular soil and climate, whether for permanent pasture or temporary ley. A knowledge of these matters will often lead to a considerable saving where a large area has to be sown. In making any selection each grass and clover should be considered with regard to its habit of growth, durability, and adaptability to soil and climate. A number of experiments have been carried out of late years by the local Agricultural Colleges with the object of ascertaining the best seed mixtures for various purposes on the soils in their particular districts. The mixtures recommended as a result of some of these trials together with others advocated by certain leading authorities, are given below, and may be used as a basis of selection for any particular soil.

Where the object is a '*temporary ley*,' and the seed-mixtures are intended to remain down for a short period only—say, one to four years—the quicker growing

and shorter lived grasses and clovers are chosen for the purpose. Thus in certain districts for a one year's ley broad red clover is sown by itself at the rate of

TABLE XXII.—SEED-MIXTURES FOR PERMANENT PASTURES.
(Quantities recommended for sowing per acre.)

	General mixture, suited to stronger soils.	Cotswold mixture, suited to limestone soils.	Cheshire mixture, suited to moist climate.	Cambridge Mixture, for poor clay soils.	Elliott's mixture.	De Laune's mixture.	Lord Leicester's mixture.
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Italian rye-grass ...	—	—	7	4	4	—	2
Perennial rye-grass...	18	18	14	3	—	—	2
Timothy	2	2	2	1	—	3	1
Cocksfoot	4	3	2	2	6	7	4
Meadow fescue ...	4	2	2	2	5	6	2
Tall fescue	—	—	—	½	2	3	1
Hard fescue	—	2	—	1	2	1	1
Sheep's fescue ...	—	2	—	—	—	1	—
Meadow foxtail ...	2	2	—	1	—	10	—
Fiorin...	—	—	—	—	—	1	—
Tall oat-grass ...	—	—	—	½	3	—	1
Golden oat-grass ..	—	—	—	¼	½	—	¼
Rough-stalked poa .	—	1	—	¾	½	1	—
Smooth-stalked poa .	—	1	—	¾	2	—	—
Crested dog's-tail ..	—	—	—	¼	—	2	—
Broad red clover ...	—	—	—	—	—	1	—
Perennial red clover	4	6	4	1½	2	1	—
Alsike clover ...	2	2	1	1½	2	1	1½
White clover ...	2	2	2	2	2	1	1
Trefoil	1	2	—	—	—	—	—
Lucerne	—	—	—	1	—	—	—
Sainfoin	—	—	—	5	—	—	—
Burnet	—	—	—	4	8	—	—
Chicory	—	—	—	1	2	—	—
Sheep's parsley ...	—	—	—	—	1	—	—
Yarrow	—	—	—	⅛	1	1	¼
Kidney vetch ...	—	—	—	—	2½	—	—
	39	45	34	33⅛	45½	40	17

12 to 16 lbs. to the acre. In other cases a certain amount of Italian rye grass, varying in quantity from 6 to 14 lbs., is sown along with the red clover. When

the intention is to leave the ley down for more than two years, a certain amount of perennial rye grass, timothy, cocksfoot, perennial red clover and white clover are added to the mixture.

The following are examples of suitable mixtures for 'temporary leys':—

TABLE XXIII.—SEED-MIXTURES FOR TEMPORARY LEYS.
(Quantities recommended for sowing per acre.)

	1 Year.	2 Years.	3-4 Years.
	lb.	lb.	lb.
Italian rye-grass	6	4	6
Perennial rye-grass	—	6	12
Cocksfoot	—	2	2
Timothy...	—	2	2
Broad red clover	8	—	—
Perennial red clover	—	6	4
Alsike	2	2	2
White clover	2	2	2
Trefoil	—	2	2
	18	26	32

MANAGEMENT OF OLD PASTURE LAND

The management of old pasture land is spoken of best under the headings of (*a*) Cultural operations on the surface; (*b*) Grazing; (*c*) Manuring.

The cultural operations on the surface include chain harrowing and rolling. These should be carried out during the latter part of winter and early spring. By chain-harrowing moss and 'fog' are dragged out, so that air can enter the soil, while dung and molehills are distributed over the surface. By rolling the land is consolidated and pressed around the roots of the herbage after the disruptive effects of the winter frosts. The slovenly practice of allowing the droppings of horses and cattle to remain undisturbed upon pastures cannot be too strongly condemned, and any manure on the

surface should be constantly scattered from time to time by knocking with forks. Unless this is done the underlying plants are for a time destroyed, and unsightly rings of dark rank herbage spring up around them.

Weeds also, which grow up in unsightly patches and usurp the surface during the summer, must be destroyed by the systematic use of the spud and the scythe.

Grazing is an important industry in many parts of the country.

On the first-class ox-pastures of the Midlands, and in some other districts, cattle are considered to feed better by themselves during the summer than when grazed with other classes of stock. On some dairy pastures, also, sheep, if grazed at the same time, are thought to deteriorate the value of the pasture for the horned stock. The best returns cannot be obtained from other grass lands, however, without a judicious mixture of horses, cattle, and sheep; and it is found in practice that one class of stock will graze after the other and browse over coarse patches of herbage growing round the manure left by the former stock.

Much skill and careful supervision are therefore necessary on the part of graziers in regulating the number and kinds of stock fed upon the land so as to obtain the best results, and to keep the grass eaten down evenly. The chief objects are: (1) To keep the stock improving; and (2) To maintain the fertility of the pasture.

Stock must not be put on too early, however, or kept on too late, otherwise the animals will be wandering about looking for a bite, and there will be a danger of some of the finer bottom herbage being torn out.

The date when cattle can be turned out in spring will depend largely on the season, but, as a rule, pastures in the South of England are ready to receive stock about the end of April. Further north, cattle are not turned out till the middle of May, or even later.

Manuring Old Grass Land.—A number of experiments on the manuring of grass land have been con-

ducted of recent years, the most important of these being a set of experiments which have been carried out at Rothamsted for a period of over half-a-century. In this case an old grass field was divided into a number of plots, and each plot has received the same manurial treatment each year, and has been cut for hay. These plots are of much interest, as not only do the returns show a difference in the yield of hay obtained each year, but an inspection shows an entire change in the

TABLE XXIV.—SHOWING EFFECTS OF VARIOUS MANURES ON THE YIELD AND COMPOSITION OF HAY AT ROTHAMSTED.

Plot.	Manure.	Yield of Hay.	Botanical Composition per cent.		
			Gramineæ.	Leguminosæ.	Other Orders.
		Cwt.			
3	Unmanured	21·5	34·3	7·5	58·2
1	Nitrogen only as ammonium salts ...	34·7	77·6	1·4	21·0
17	Nitrogen only as nitrate of soda ...	35·5	43·8	3·4	52·9
7	Mineral manures, no nitrogen ...	40·9	20·3	55·3	24·4
4-2	Phosphoric acid and nitrogen, no potash	35·8	91·5	—	8·5
9	Complete manure, nitrogen as ammonium salts...	54·8	91·2	1·3	7·5
14	Complete manure, nitrogen as nitrate of soda	60·8	88·8	3·7	7·5
11-1	Complete manure, excess of nitrogen	66·8	99·2	—	0·8

botanical composition of the herbage of the several plots, which at the commencement of the experiment was of a similar character.

The effect of this long-continued manuring on the yield and botanical composition of the herbage of the various plots is well shown in Table XXIV., which gives the average yield for fifty-three years, and also the character of the resulting herbage, as shown by a botanical analysis in 1902, the forty-seventh year of the experiment.

Certain facts are shown by this table. Thus, if grass land is mown each year without any return in the form of manure not only will the yield be small, but there will be a great preponderance of weeds in the composition of the herbage. One-sided manuring, only supplying nitrogen or only phosphoric acid, however successful at first, will eventually result in increased impoverishment of the land. Nitrogenous fertilizers encourage the growth of the grasses at the expense of the clovers. Mineral manures, and particularly potash, encourage the growth of leguminous plants, and enable them to make headway against the grasses.

These experiments also show that any special manuring or treatment followed continuously will encourage the growth of certain species of plants as against others, and the best results are therefore obtained by the treatment first selected.

In a similar way laying up land for hay will encourage the development of the stronger grasses; whereas when a field is grazed the finer bottom grasses will have the advantage. Taking these facts into consideration, it therefore seems advisable to keep certain lands for mowing each year and to graze others, rather than to follow the custom of alternately haying and mowing, in which case certain grasses are encouraged one season and repressed the next.

Again, it is a waste of money to lavish expensive dressings of manure on poor grass-land unless a proper herbage is present to take advantage of such treatment. In such cases the character of the herbage must be first slowly reformed by judicious treatment; and it is only when the better grasses and clovers have been encouraged to appear that it will pay to use complete dressings of manure.

Taking into account the above facts it will now be possible to deal separately with the question of manuring pasture and meadow land respectively.

Manuring Pastures.—Pastures of the better description, such as old feeding pastures, require very little manuring, as the stock being fattened on such land remove few fertilizing ingredients from the soil. When

cake and corn are fed the fertility actually increases in these soils. It is a mistake to use heavy dressings of farmyard manure on land of this description, as it will encourage the growth of the coarser grasses and weeds to the exclusion of the clover. In old pastures an abundance of white clover is generally in evidence; and this will accumulate nitrogen in its growth and store it in the surface soil. The cheapest method of supplying nitrogen to pasture land, therefore, is by encouraging the growth of clovers.

Most grass lands, especially on soils naturally deficient in lime, will pay for dressings of this material from time to time. The beneficial action of lime is particularly noticeable on grass land where organic matter has accumulated through the decay of vegetation and addition of dung, and the soil is consequently somewhat sour. The application of lime in such a case is often followed by a luxurious growth of grass and clover, owing to the acidity being neutralized and reserves of plant-food being rendered available for the use of the plant by the action of the lime.

Lime may be applied to grass land in the form of quicklime, but one of the handiest forms to use at the present time is 'ground lime,' which can be purchased in bags, and is in a sufficiently dry state to sow from a manure drill, by which means a small dressing can be evenly distributed. Ground lime may be used at the rate of 10 to 20 cwt. per acre on grass land.

It is a practice with the graziers in the better districts to make a compost heap of road scrapings, cleanings from ditches and other refuse about the farm. This is mixed with lime and turned over two or three times, after which it is applied as a top dressing to grass land with the most beneficial results.

Good pasture land, although rich in nitrogen, is sometimes deficient in mineral ingredients, and, therefore, additions of potash and phosphates in some form are often advisable.

Such a dressing might consist of—

Superphosphate	3 cwt.
Kainit	2 ,,

applied at the rate of 5 cwt. per acre early in the year; or, especially on soils deficient in lime, 5 cwt. of basic slag put on in the autumn will have a good effect in maintaining the quality of the herbage.

Poor pastures, with a thin herbage on clay, sand, or chalk, require special treatment in each case to improve them. As has already been stated, it will not pay to use expensive dressings of manure on these pastures till the herbage has been slowly reformed.

In the case of poor clay land, as at Cockle Park, in Northumberland, a heavy dressing of basic slag up to 10 cwt. per acre will often have the effect of stimulating a strong growth of the weak clover plants which are languishing in the soil through deficiency of phosphates. When this has been effected nitrogen will begin to accumulate in the surface soil, and the better grasses will gradually assert themselves as the clover disappears. After the herbage has been thus reformed a more liberal manuring may be followed, including caking through the stock grazed upon the land.

Poor sandy soils often require supplies of potash in the form of kainit, in addition to phosphates, to improve them. In these cases steamed-bone flour is a good form in which to supply phosphates.

Thin pastures on chalk soils require very liberal treatment to improve them. They will stand plenty of dung and heavy cake feeding, as well as complete dressings of artificial manures. In many cases it is doubtful whether pastures of this description can be economically improved. On limestone soils, such as are found on the Cotswold Hills, superphosphate will often be found to give good results in improving the herbage.

Manuring for Hay.—In the case of land which is laid up for hay the object is to obtain a bulky crop of strong growing grasses all coming to maturity, as far as possible, at the same time. With this object in view it is advisable to manure heavily, using large dressings of farmyard manure and complete dressings of artificials. Where a field is cut regularly for hay each year, the most economical system of manuring seems to be a dress-

ing of farmyard manure (some 10 tons per acre) every third or fourth year, and applications of complete mixtures of artificial manures during the intervening periods. Such a mixture would consist of 3 cwt. per acre of superphosphate and 2 cwt. of kainit applied early in the year, followed by 1 cwt. of nitrate of soda as soon as the grass showed signs of starting growth.

On some of the stronger soils where there is sufficient available potash, basic slag seems to give better results than superphosphate as a manure for the hay crop. In such cases 5 cwt. per acre of basic slag put on in the autumn, followed by 1 cwt. of nitrate of soda when growth starts in the spring, may be looked on to give good results, kainit being omitted.

MANAGEMENT OF MEADOW LAND

A **permanent meadow** is a field which is mown annually for a hay crop. The land may be grazed early in the year, and then the stock are turned off some time in April, and it is shut up so as to leave time for the grass to grow previous to cutting. Before finally shutting up it is a good plan to chain-harrow the field so as to spread the dung, and also to roll it to consolidate the soil round the roots of the plants. At the same time all sticks and stones, which otherwise might cause trouble at the time of mowing, should be picked off the surface and removed.

The various sorts of hay commonly met with in this country are:—

(*a*) Upland or meadow hay; the produce of permanent grass land.

(*b*) 'Seeds' hay which is yielded by temporary leys, sown with grass and clover seeds.

(*c*) Water-meadow hay obtained from irrigated meadows. This as a rule requires a good deal more making than ordinary meadow hay, and often has to remain in large cocks or 'summer ricks' in the field before being finally carted home.

HAYMAKING

Haymaking is the operation whereby grass and clover crops are converted into dry fodder. It includes the three processes of (1) Cutting; (2) Making; (3) Carrying.

Cutting.—Meadow hay is essentially a straw crop, the object being to secure it before the grasses begin to ripen their grain—that is, before the nutrient ingredients in the stem have migrated upwards to aid in maturing the seed. Hence, hay should be cut at about the time the bulk of the grasses are coming into flower—that is, just before the pollen dust can be freely shaken from them.

The mowing machine is now very generally employed for cutting hay, though the scythe has still to be used in water meadows and on embankments. The introduction of the mowing machine has increased the risk lest too much grass be cut at one time for the available hands to deal with, so that this is a detail requiring attention. The labour of mowing with the scythe is very severe, and it brings into play nearly every muscle in the body. An experienced workman will mow from ¾ acre to 2 acres per day, according to the heaviness of the crop. The line or row of cut herbage as it falls upon the ground is called the **swathe.**

There is a notable difference in the mode of cutting by the scythe and by the mowing machine. The simpler implement effects the clean cut of a knife. The machine, which works on the scissors principle, not only cuts, but crushes or bruises at the same time. The cut of the scythe is regarded as being the less injurious to the standing plant, and some farmers always prefer the scythe for meadow hay.

Making.—The conversion of green grass into hay is effected by loss of moisture, which is brought about partly by the sun's heat and partly by the wind. How great is this loss may be gathered from the circumstance that freshly-cut grass contains from 70 to 80 per cent. of water, whilst hay has only from 14 to 16 per cent. To promote the escape of water vapour

it is necessary for the cut herbage to be turned over, and shaken out, in order to expose as large a surface as possible to the air. At the same time, the work should be carried out in such a manner that, on the approach of rain, the material can be quickly gathered together, so as to expose the least possible surface to its action. Hence there is plenty of room for skill in the operation of haymaking.

The grass falls from the mower in thick swathes, which, if left undisturbed, would at length rot inside. Therefore they must be **tedded**—*i.e.*, shaken out or turned over in some way. This is done either by the hand-fork, or by means of a tedding machine, or a swathe-turner.

It must here be remembered that the methods of haymaking have undergone considerable changes of recent years. Formerly the grass was all cut with the scythe, and afterwards tedded out with the fork. The process of haymaking in these circumstances being entirely carried out by hand was tedious and expensive.

The next step in advance followed on the introduction and development of labour-saving machinery, when the mowing machine, the horse-rake, and the 'tedder' came into common use on the farm.

More recently other implements have gradually been added to assist in the hayfield, so that we now have the 'swathe-turner,' 'side-delivery rake,' 'hay-loader,' and 'sweep-rake,' together with the 'elevator' and hay-fork, which can be used under suitable conditions to minimize labour in saving the hay crop.

A large portion of the hay crop is made in the southern portion of England in the 'swathe' by means of the **swathe-turner.** When sufficiently dry the swathes can be run together by means of the **side-delivery rake** into parallel rows across the field known as 'wind-rows,' which can easily be split up into cocks when necessary as a protection from the weather; or the hay can be loaded directly from the wind-row into the carts and waggons. During a wet summer, however, and when the crops of grass are heavy, the **tedder**

will be found to be a machine that it is almost impossible to dispense with.

The process of making meadow hay when the tedding machine is used may be described as follows.

The crop, when ready, is cut with the mowing machine, the grass being left in the swathe, so that the water may evaporate from the surface. The next day it is 'tedded,' or spread out in a thin layer over the surface of the ground to dry. Sometimes when the grass is cut early in the morning, and the weather is fine, the tedder is set to follow immediately after the mowing machine. The next operation is 'hacking,' or collecting the hay together into small wind-rows, which may be run together into little 'pooks' or 'cocks' for the night.

The following morning these are thrown out into beds as soon as the ground is dry, and the tedding machine may be again set to work along these beds, if necessary.

The hay is then collected by means of the horse-rake into large wind-rows, which can be run up into large cocks for the night, or the hay can be carried direct from the rows as circumstances require. If put into large cocks, these should be turned over the next day as soon as the ground is dry, and if the weather is fine the hay should be fit to cart the same day.

The foregoing instructions apply to a period of fine weather, and would occupy a period of some three days. When the weather is unsettled or catchy, however, the period for carrying out these various operations has to be considerably extended; and it may be necessary to continue the process of throwing the hay out into beds, and cocking it up again for several days in succession.

If hay is carted before it is ready, it may cause serious trouble by overheating when put together in the stack.

Carrying.—The hay is carted from the field to the stack in carts or waggons, the material being loaded on to these by hand. In some cases a machine of American origin, working on the elevator principle, and

called a **hay-loader**, is used for picking up and putting the hay on to the carts, thereby making the process of haymaking less dependent on manual labour.

Another labour-saving implement, also introduced from America, the use of which is gradually spreading, is the **sweep-rake**. This machine, which consists of a large frame on wheels drawn by two horses, is able to sweep up the hay out of the cock or wind-row and take it straight up to the rick, thus saving the expense of carting. Its use is restricted, however, to cases where the stack is built in the same field from whence the crop is taken.

The **time** when hay is fit to carry and put into the stack will depend very largely on the bulk of the crop and the character of the herbage. When hay is composed of grasses of a somewhat dry and benty nature, it is not necessary to be so careful about its condition when carting as when dealing with a crop in which there is a large percentage of bottom growth and clover. In this latter case discretion must be used, as otherwise excessive heating, and in some cases spontaneous combustion may take place in the stack.

In the damper climate of the north of England and Scotland the custom is to put the hay up into large cocks or 'summer ricks' in the field, containing half a load to a load, with the object of allowing the hay to dry more thoroughly and sweat to a certain extent before it is carted some weeks later to the large rick. This method also has the advantage of saving time in securing the hay crop at a busy time of the year, the final carting and building into stacks being left till a favourable opportunity presents itself.

The ordinary **stacker**, or **elevator**, will be found most useful for emptying the carts on to the stack, and will save a lot of manual labour in pitching, especially when the stack rises in height. The hay-fork worked by means of a pulley from a cross-piece attached to a long pole set in the ground, will also be found a valuable implement when stacking hay, as it is able to raise a large part of a load from the cart on to the top of the stack at one lift.

Care must be taken in building a stack that the middle is kept as high as possible, otherwise the roof will become too flat when the stack settles down, and the thatch will be unable to remove the water sufficiently rapidly. The walls should also be carried up in such a way that the eaves stand well out from the base, so that the drip from the roof may fall clear of the sides.

General Haymaking Rules.—To obtain the best results attention must be paid to the following points in carrying out the process of haymaking.

Throughout the entire operation the crop should be dealt with as gently as possible. Turning and shaking out are, of course, necessary to assist the process of drying, but rough handling should be avoided. Grasses are covered with a delicate waterproof coating of waxy material, and when this is broken or injured water will soak into the stalks, and the quality of the hay will be much damaged by the soluble ingredients being washed out. This loss is especially liable to take place when half-made and tedded hay is washed by rain. The proper time to cut is when the bulk of the grasses and clovers are coming into flower, and before they set their seed. In this connection it must be remembered that any loss of weight in the crop by early cutting will be gained in the aftermath. Much greater damage, however, will be done to hay by cutting and allowing it to be washed for days by rain than by allowing the grass to become somewhat old before cutting.

In making **clover hay** great care must be taken to handle it as little as possible, and it must not be tedded, otherwise much loss may occur by breaking off the fine leaf. It is best, therefore, to let the crop remain a few days in the swathe after it is cut to allow the upper surface to dry thoroughly, and then to gently turn it with the hand-rake or swathe-turner, so that the under surface may be exposed. After a time it may be turned back again, and then gently put together in rows—three or four swathes being put into one row—from which, when

fit, it should be carted direct, and putting it up into cocks should be avoided, if possible.

Lastly, it is a good rule to observe, and one of great importance now that, by means of the mowing machine, so much grass can be cut in a day, that no more hay should be got on the ground than the staff at command can work.

Sweating.—When put together in the rick certain chemical changes take place in the new hay which give rise to the production of heat and sweating.

The amount of heat developed in a stack will often largely determine the quality of the hay when it is cut out. The fermentation which takes place in the stack is brought about by the starch in the grass being changed first into sugar, and then passing through the successive stages of alcohol, acetic aldehyde, and finally acetic acid.

Overheating is due to an excessive development of a suffocating, inflammable gas known as *acetic aldehyde*, and where this occurs not only may the hay be charred and its qualities for feeding spoilt, but spontaneous combustion may even take place in the stack.

A good sweating will often improve the subsequent quality and palatability of hay of a somewhat coarse character when put together, but the fermentation should stop at the sugar stage; and to obtain this the hay must be dry and in good condition when stacked.

The temperature of the stack can be tested by means of a thermometer, and a good sweating can be safely allowed up to 140° F. Danger is to be expected, however, if the temperature rises above 150° F. Where this occurs it may be necessary to cut a hole in the stack to allow the air to enter, or even in some cases to turn the stack over again.

The **quality of hay** is judged by its odour, its colour, and its general appearance. Hay that has been well saved has an agreeable aromatic odour, almost lavender-like, whilst its colour is pale green. Its appearance is uniform in all parts of the stack, and there is no sign of mildew. When a stack *heats*, the middle is, of course,

browner than the outer parts. As it increases in age, hay acquires a fuller and more pronounced odour, its colour deepens, and it cuts out from the stack in more compact form.

The desirable qualities which have been mentioned are absent from hay that has been badly washed in the field, or has been put into stack when too damp, and has consequently heated to too great an extent, and perhaps has subsequently become mouldy. Such hay acquires a very dark colour, it has an unpleasant odour, and samples from different parts of the stack are likely to be uneven in quality. Its feeding properties are lessened, and its selling value is diminished.

Another method of judging hay, too little followed, is based upon its botanical composition. The student should not be satisfied with learning to identify plants as they grow in the meadow. He must proceed a step farther, and be able to recognize them, and even fragments of them, as they occur in the dried state in the stack. Separate a bundle of hay into *gramineous*, *leguminous*, and *miscellaneous* heaps, and then try to identify the species present in each heap. The panicles of the grasses will be recognized without much difficulty, and by practice it becomes possible to identify the leaves and culms as well. 'Seeds' hay, ordinary meadow hay, and water-meadow hay can respectively be identified by an examination which results in the recognition of the species of plants present. To take two extreme cases, hay consisting largely of rye grass and clover would at once be accepted as superior to hay in which the woolly stems and leaves of Yorkshire fog, and the brown withered fragments of sorrel, were abundant

Hay is considered as 'new' up to Michaelmas Day (September 29), and, in some districts, till it is a year old. A load of old hay is 36 trusses, and as the truss weighs 56 lb. (½ cwt.), the load will weigh 18 cwt. A load of new hay, at 60 lb. per truss, weighs 19 cwt. 1 qr. 4 lb. A load of straw, at 36 lb. per truss, weighs 11 cwt. 2 qr. 8 lb. In each case the load is 36 trusses. Preferably, hay and straw are sold by the ton, and not by the load.

ENSILAGE

The process of preserving green fodder in its succulent condition, instead of first drying it into hay, is called **ensilage.** The **silo** is the receptacle in which the preserved material, to which the name of **silage** is given, is stored. It is only within comparatively recent years that the process of ensilage has been practised on any extensive scale in this country, but during that time the operation has been much simplified. It was, for example, formerly thought that an air-tight receptacle must be available in order to make good silage. So far, however, is this from being the case, that silage is now made without any receptacle at all, the heap or stack of the material itself constituting the silo. But, though the practice has been modified, there has been no change in the principle, the leading feature of which is the exclusion of air from the mass of green herbage.

In the case of farmyard manure it is a familiar fact (*see* p. 110) that the more tightly the dung-heap is compressed—that is, the more completely the atmospheric air is excluded—the slower are the changes that take place within the heap. On the other hand, the greater the freedom with which air permeates the mass the more rapid is the fermentation. In ensilage the object is to imitate, and indeed to improve upon, the tightly pressed dung-heap, and, by excluding the air, to prevent oxidation, which brings in its train fermentation, decay, and loss. The more thoroughly the air is excluded, the greater is the success in making silage.

Grass is the material usually converted into silage, and, in wet seasons unfavourable to haymaking, much useful provender has thus been saved which otherwise would have been lost. The process is, however, equally applicable to any other kind of green herbage. If put into specially built silos, the herbage is often cut into chaff first, as it then packs more closely, thus promoting the exclusion of air. In stack silos the material is put up in the long state.

Specially built silos are constructed of brick or stone, and may be above ground or below ground. Chalk-pits,

gravel-pits, and other excavations, particularly if on sloping ground, which facilitates filling, may likewise be adapted as silos. In all such cases, the chopped herbage requires to be well packed and trodden, especially at the sides, so as to completely fill the receptacle. Even then, the shrinkage which takes place may create an air space between the mass of herbage and the sides of the silo.

The **silo stack** possesses the advantage of cheapness and simplicity, and nothing beyond ordinary care is necessary to ensure success. For the purpose of making such a stack or clamp, grass may be mown when the majority of the plants are in bloom; clover when the whole crop is in flower; peas and vetches just when the pods are forming, but before they commence filling; oats and other cereals when the grain commences to form; and rough trimmings from banks and ditches at any time when they can be used to form the top layer. In selecting a place for the clamp, advantage should be taken of hill-sides, so that the 'drawing-up tongue,' leading on to the clamp, may be as shallow as possible, thereby lessening the quantity which will require turning up when finishing the clamp. It is best to cart immediately after the grass is cut, unless the material be exceptionally succulent, as is the case with sewage-grown grass; the weight of the fresh herbage thus helps to ensile that below it. The material should be carted together in such a way that the horses and carts cross it, thus consolidating it; and a roller, drawn by one or more horses, should be used to press it down, and make it more easy for horses to cart over. The carts, roller, and horses would not provide sufficient weight to compress the mass at once into the compact condition in which it comes out as silage, and which weighs from 50 to 60 lb. per cubic foot. But when fermentation takes place, the fibre in the material softens, and readily undergoes compression.

Not more than three days should be allowed to elapse before carting fresh material upon the heap, otherwise the surface of the latter will become mouldy. This point must also be considered with reference to the

sides, which should be kept hand-pulled, or pared, daily, failing which the portion taken off the sides will be in a mouldy condition when put on the top. The greatest care must be taken to keep the sides upright, and they should receive additional rolling on the top in order that they may be properly compressed. The carts should be led round as near the sides as possible for the same reason. It will be found necessary to maintain the sides higher than the middle, as it is impossible otherwise to keep the stack in proper shape. When all the material has been brought to the clamp, the inclined plane of herbage which formed the tongue should be turned up so as to ensure that the whole of the top shall be of uniform height when it has settled. The clamp should be covered as soon as possible, for less waste will result than when it is allowed to become dried on the top. If, during intervals of making, the surface dries, it should be watered, in order that an even sample may result. As to weighting, it is a common practice to build a haystack on the top of the silo stack to provide the pressure required, and this answers admirably. As there is waste at the sides of all silage, it is advisable to build large stacks or silos, so that the extent of the sides may be proportionately lessened.

Another cheap and efficient method of making silage is to dig a pit in the ground 3 to 6 ft. deep, cart over it, and tread it with horses and men on the outside. Roll it, and cover it all over—sides and top—with the mould from the trench, and knock it down lightly. A stack of hay built upon it then makes a capital covering.

If care is taken to pack the material close to the walls, the loss is considerably less in the case of silage made in silos than when it is made in the stack, therefore small quantities are more successfully preserved in the specially constructed silo than in the stack.

Silage may be fed to cattle at any time it may be required after it is once put together. It will keep good for years if well secured. Inferior hay may be got rid of by chaffing it up with silage before offering it to stock.

Whether sour silage or sweet silage results from the

operation of making is determined mainly by the temperature at which fermentation takes place within the mass of herbage. Silage is sour or sweet according as there is much or little of certain organic acids present. These acids are principally acetic, lactic, and butyric.

If an open-air silage stack is viewed in section from top to bottom, the lower layers will be seen to be greener than the upper, whilst the colour gradually becomes browner towards the top, which will be almost of a burnt coffee colour. The bottom layers have been converted into green or sour silage because the pressure of the material above has excluded the air, and fermentation has taken place at a low temperature, there not having been sufficient air to supply the oxygen for a high temperature fermentation. As less weight was applied to the upper portion, there was *freer* access of air to it, and more air was retained among the mass—hence a higher fermentation. The colour thus affords an indication of the temperature at which the fermentation took place.

It is generally recognized that silage made at a temperature below 120° F. is 'sour' silage, whilst that which has not risen above 90° F. is commonly spoken of as 'low-temperature sour,' and that which has exceeded 90° F. as 'high-temperature sour.' Between 120° and 130°, there are generally veins or seams of sweet and sour silage intermingled. From 130° to 140° a shade of brown is discernible. Between 140° and 160° it is decidedly brown; and above 160° it is over-heated, and very similar in appearance to over-heated hay, whilst the flavour denotes burning. In any case, fermentation ceases as soon as all the available oxygen is used up, the air that exists amongst the herbage being then rich in carbonic acid gas.

Inasmuch as fermentation is a process chiefly of oxidation, the loss of solid matter falls mostly upon the carbonaceous compounds (the carbohydrates) of the herbage. The total quantity of nitrogen remains about the same, although some of it is converted into a form in which it is less available as food. When 'sweet' silage is produced it is due to the higher temperature

having killed the living organisms which, under conditions of less heat, set up an acid fermentation. The loss of solid matter is probably greater in the making of 'sweet' silage. The odour of sweet silage, however, being vinous or aromatic, is far from unpleasant. 'Sour' silage, on the other hand, has a powerful and not an attractive odour, which is readily absorbed by milk freshly drawn from the cows. Therefore sour silage should not be allowed to lie about the stalls of dairy cows, nor should people handle it immediately before milking.

Though ensilage affords a most useful alternative when the weather is too unfavourable to permit the saving of hay, it should not be regarded merely as a substitute for haymaking. Silage can be made in all kinds of weather, and it is capable of affording a succulent and nutritious food to stock at all seasons of the year. Consequently it possesses a special value in seasons when there is a dearth of roots.

CHAPTER XVI.

FARM CROPS

THE soil, or 'land,' as it is more commonly termed by those who work it, is divided, for agricultural purposes, into grass land and arable land.

Grass land is subjected to very little cultivation; it cannot be stirred deeply, as the growth upon it is permanent. The acts of cultivation are limited, therefore, to harrowing and rolling.

Arable land undergoes frequent turning and stirring, these operations being necessary to provide suitable seed-beds for the crops, the seed for which is in most cases sown at least once a year. It is unusual to grow the same kind of crop frequently on the same land, it being more economical to grow a variety of crops.

ROTATION OF CROPS

Experience has shown that, by growing different kinds of crops in a particular order, reliable results may be looked for. In this way there have arisen recognized systems of cropping which are called **rotations.**

The **advantages of rotations** are:—

1. They result in crops of greater vigour. When crops of the same kind are grown continuously on the same land they are more liable to be attacked by insect and fungoid pests. Repeated cropping of the same kind causes the crops to lose vigour, so that they are rendered less able to withstand such attacks. Therefore fresh kinds of plants should be introduced upon the land. This variation of the order takes away the food of insects which infest a particular crop, so that, by the time this crop is grown again, the insects have either died out, or have gone elsewhere in search of food.

2. They are economical of manure. Different crops require different kinds of manure, so that an alteration in cropping allows plants of the various orders to take up the manurial foods in the respective proportions in which they need them, some crops requiring more of one kind, and others more of another. A balance is thereby maintained amongst the manurial ingredients in the soil.

3. Well-arranged rotations allow of an economical distribution of labour, whether applied to the cleaning of the land, the sowing of the seed, or the application of manures.

4. Some varieties of plants (clovers, etc.) store up food, from the air or soil, which becomes available for the use of succeeding crops. Other crops (root crops, etc.) are restorative, not in themselves, but because they are usually fed to live-stock upon the land. Some (wheat, barley) are of such a nature that, while they are still growing, other kinds may be seeded in amongst them, and so may become established, thereby avoiding loss of time. Shallow-rooted crops are alternated with deep-rooted ones, because they draw their food from different regions of the soil.

5. A variety of crops is essential where cattle and other live-stock are kept.

The most typical rotation is the **Norfolk** or **four-course system.** This is as follows:—

First year: Autumn-sown cereal crop.—Wheat.

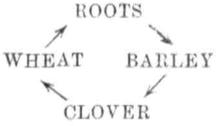
Second year: Fallow crop.—Roots: Turnips, mangels, cabbage, potatoes, etc.

Third year: Spring-sown cereal crop.—Barley or oats.

Fourth year: Leguminous crop.—Clover, in mixture or alone; peas, beans.

Fifth year: Same as first—and so on.

The general arrangement, therefore, is such that about half the land is under white straw crops, whilst the other half is carrying green crops and clover, and the rotation may be thus represented:—



This rotation is suitable for many classes of soil, for, where one of the crops named would not be likely to prosper in a particular case, another one of the same general character could be substituted which would do so.

There are many rotations extending over from four to eight years, but it will be found on examining a classified list of such rotations that they are to a great extent founded on this four-course system, and that the chief differences are in the extension of the time during which the clover or 'seeds' crops are allowed to stand, and in the introduction of a wheat crop, or of some other exhausting crop, after roots, before barley is sown. Shorter rotations are also known, but they are practised less frequently than in bygone years, as the soils to which they are applicable are now found to be unprofitable when under any form of arable culture; consequently, this class of land has, to a great extent,

gone out of cultivation. Nevertheless, the two-course system—(1) wheat, (2) beans—does exist, though, as an occasional bare fallow has to be taken which upsets this order, it can scarcely be regarded as an exclusively two-course system.

An examination of the four-course shift serves to show how admirably a well-arranged rotation adapts itself to farm practice:—

First year: Wheat.—The wheat follows clover. Sheep can find but little food on the clover after September, therefore at this period it is ploughed. By employing the horses at this time of year the work in the spring is lightened, which is a very important matter. The clover stores up in its roots and stubble a large quantity of food ingredients, particularly nitrogen and potash, which are ready for the use of the wheat crop. These and other ingredients have been extracted partly from the air by the broad leaves and root-nodules of the clovers, and partly from the soil by their deep-searching roots, which are capable of striking vertically into the land for some yards. The wheat crop provides straw for thatching, and for fodder and litter for cattle. If the clover ley is wanted for the sheep in the latter part of autumn or beginning of winter, a crop of oats may be substituted for wheat, as oats can be sown in the spring: this is not an uncommon practice in Scotland.

Second year: Fallow crop.—The land has carried, during the three previous years, crops which have afforded but few opportunities of deep stirring or cleaning, provision for which must be made. Two out of the three crops have been exhaustive, so that a restorative crop is advisable. A bulky crop of succulent food for sheep and cattle is required at the same time. All these are provided for in fallowing by means of a fallow or root crop. After the spring corn is sown, work is required for the horses and men, and they can be employed on the fallows with great advantage. Perennial weeds are drawn out by the implements of tillage, and annual weeds are destroyed by surface hoeing after the crop is up.

Besides the practical advantage arising from the opportunity which the growth of roots affords for the cleaning of the land, the benefits of growing this crop in rotation are further due to the large amount of manure applied for its growth, to the large residue of the manure left in the soil for future crops, to the large amount of matter at once returned as manure again in the leaves, to the large amount of food produced, and to the small amount of the most important manurial constituents of the roots which is retained by the animals consuming them, the remainder being returned to the land as manure.

Third year: Spring-sown cereal crop.—Barley and oats thrive best when seeded early in the spring. There is consequently little opportunity of cleaning the land. Such crops are therefore adapted to follow the fallow or cleaning crop. In some seasons when, on account of the weather, but little work can be done upon the land, it is difficult to prepare a seed-bed. This difficulty rarely arises after fallowing, as the land has been thoroughly turned, stirred, and lightened only a few months previously, so that nothing beyond shallow ploughing is necessary to form a seed-bed. Thin furrows are more easily reduced to a tilth than are thick ones, as the weather has better opportunities of mellowing them, and less horse-power is necessary to apply the mechanical force required to bring the clods within the influence of wind, rain, and frost. Barley flourishes best when the seed-bed is just deep enough to cover the seed well, and when the subsoil is fairly light, but firm enough to afford efficient root-hold to the plants. When the land works rather badly, so that the mellow tilth required by barley cannot be obtained, oats may be substituted. They are more vigorous, and are not so susceptible to injury when sown on a somewhat moist and rough seed-bed. Again, when the land is too heavy for barley, oats may serve as the crop sown at this period of the rotation.

At this stage a **comparison of wheat and barley,** which normally occupy the alternate second years of the rotation, is instructive. Wheat, as a rule, is sown in

autumn, in a heavier and closer soil, and has a period of four or five months in which to distribute its roots, and thereby get possession of a wide range of soil and subsoil, before barley is sown. Barley is seeded in a lighter surface soil, and, with a shorter period for root development, is in a much greater degree dependent on the stores of nutriment within a very moderate depth; it is, in fact, a 'surface feeder.' It has, therefore, to rely more especially upon the surface soil for its nitrogenous, and particularly for its mineral, supplies. As a result, barley is more benefited by the direct application of mineral manures, especially of phosphatic fertilizers, than is wheat under similar conditions of soil. As both crops are exhaustive of the nitrogen of the soil, they alike require—in the ordinary course of farming—nitrogenous manures, whilst the spring-sown crop, barley, needs superphosphate also. Besides its position in the ordinary course of rotation, barley may be grown in direct succession to wheat on the heavier soils, and, provided the land is clean enough for a second corn crop, will then yield well both in quantity and in quality.

Fourth year: Leguminous crop.—Where possible, a restorative crop should be taken after an exhaustive one, especially where sheep-feed for summer use and hay for winter use, are required. These conditions are complied with when a clover or 'seeds' crop is introduced. Clovers require firm seed-beds, and these are available when the clovers are sown after barley. As the clover crop is intended to lie for some time, it should be sown not long after the land has been cleaned by being fallowed. As a rule, the clover is actually sown immediately after the fallowing. As it requires to be in the land a full year before it can give a return, it is sown about the same time as the barley or oats, so that the two crops are on the land at once, the clover establishing itself whilst the barley is maturing. In this way there is a saving of a year, which would be lost if the clover were sown on uncropped land. Should the land be clover-sick (p. 350), the difficulty is met by planting beans when the soil is heavy, and peas when

the soil is light and friable, thus giving the land a rest from clover, and allowing an opportunity for it to become healthy again. Also, if the land is considered too foul for clover, beans or peas may likewise be taken, as an opportunity is thereby afforded of cleaning the land slightly before seeding, and of cleaning it more thoroughly by a bastard fallow (*i.e.*, a short fallow at the end of summer) immediately the crop is cut, and before wheat is sown. In Norfolk, where comparatively few beans and peas are grown, red clover is usually taken once in eight years. In the intermediate fourth year, a mixture is sown of trefoil, white and alsike clovers, and rye grasses, the crop being very often fed, and not cut for hay.

The foregoing indicates the principles of a well-known rotation, and of one which is found easy to work, though it does not follow that it is in all cases the best. Others are adapted to suit particular circumstances, and a sound farmer should be competent to introduce a modified rotation to meet his special requirements.

The following are examples of rotations, being mostly adaptations from the four-course followed in various parts of the country.

1. **8-course rotation suitable for heavy soils** formerly followed in the vale of Gloucester:—

1st	year.—	Fallow crop (vetches followed by bastard fallow).
2nd	,,	Oats.
3rd	,,	Beans.
4th	,,	Wheat.
5th	,,	Bare fallow
6th	,,	Oats.
7th	,,	Clover.
8th	,,	Wheat.

2. **5-course rotation** used on the **better loams** in the Midlands:—

1st	year.—	Roots (swedes).
2nd	,,	Barley (seeded with clover)
3rd	,,	Clover.
4th	,,	Wheat.
5th	,,	Oats (manured).

3. **5-course rotation** followed on **limestone soils** of the Cotswold Hills:—

1st year.—Roots (swedes).
2nd ,, Barley or oats (seeded).
3rd ,, Seeds (mown).
4th ,, Seeds (grazed).
5th ,, Wheat.

4. **6-course rotation** suited to **damp climate** of the north-west of England:—

1st year.—Roots (swedes and sometimes potatoes).
2nd ,, Oats (seeded).
3rd ,, Seeds.
4th ,, Seeds.
5th ,, Seeds.
6th ,, Oats or wheat.

5. **5-course rotation** used on **deep marly loams** in Cheshire:—

1st year.—Roots (largely consisting of potatoes).
2nd ,, Wheat (seeded).
3rd ,, Seeds.
4th ,, Seeds.
5th ,, Oats.

6. **6-course rotation** adopted on **good limestone soils** in Derbyshire:—

1st year.—Roots (turnips and swedes grown with artificials).
2nd ,, Barley or oats (seeded).
3rd ,, Seeds.
4th ,, Seeds.
5th ,, Wheat (manured with farmyard manure).
6th ,, Oats.

7. **Wiltshire 8-course rotation** suited for **sheep-farming**:—

1st year.—*Catch-crop* (such as vetches, trifolium, etc., followed by late sown turnips).
2nd ,, Roots (swedes).
3rd ,, Wheat.
4th ,, Barley.
5th ,, Roots (preceded by an early catch-crop such as winter rye).
6th ,, Barley (seeded).
7th ,, Clover and seeds.
8th ,, Wheat.

CORN CROPS

WHEAT.—The wheat crop generally follows 'seeds,' peas or beans, or potatoes, and is occasionally taken after roots fed off in the autumn, bastard fallows, or bare fallows. Before seeding, the dung should be carted out on the land at any convenient time after harvest, or directly the hay is off, so that it may be ploughed in.

The soils best suited for the growth of wheat are those of the heavier description, such as the clays, when properly drained. Wheat also requires a dry climate and plenty of sun to bring it to maturity, and therefore it is better adapted to the south and east of England than to the more humid districts of the north and west.

After 'seeds,' the preparation of land for wheat is generally simple, for it is not advisable to stir the furrows unless a thorough cleaning is intended. The land is therefore only ploughed and, on very light soils, ring- or furrow-pressed. The seed is either drilled or sown broadcast, and harrowed in.

After peas or beans, the land is usually ploughed and stirred to get out couch, and left to consolidate, wheat being found to stand the winter best on a firm seed-bed. Just before seeding, the surface is harrowed, care being taken not to reduce the clods more than is absolutely necessary, as when the land is left in a fine state on the surface it runs together, forming a cement-like covering on drying in the spring, or, as it is frequently called, a 'winter cap,' which is often very hard and troublesome to break. If not broken, it effectually prevents the wheat from growing freely.

After potatoes the land is often light, and the aim should be to consolidate it, without reducing it too much on the surface. A shallow ploughing to make the bed even and level is in some cases practised, whilst in others the land is merely drag-harrowed into a seed-bed, thus retaining as solid a bottom as possible.

After roots which have been fed off, the land should be ploughed very shallow, so as to retain firmness below, only sufficient soil being moved on the surface to permit

the seed being covered. Occasionally, on heavy land, it is advisable to sow the seed broadcast behind the sheep, and 'plough it in.' When this is done, it is only necessary to plough to a depth of from 1 to 1½ inch, letting the furrow fall flat. No harrowing is required until spring, as the frosts will cause the land to shatter, thus providing a proper surface.

After bastard and bare fallows the corn must be drilled; otherwise it will not be properly covered by the soil. The seeding should take place early; in fact, this is the earliest of the wheat land to be seeded. As the plant generally grows quickly and stoutly, thin seeding is advisable; 5 pecks per acre are sufficient on a fallow in September, where 8 to 10 pecks would be necessary on the same land if it were in clover ley not broken up until the end of October. The land, for some time before seeding, should not be deeply stirred, but be allowed to consolidate. The surface consolidation should be effected by harrowing, to prevent its becoming too fine, though there are occasions when wheat land becomes light and puffy, and when pressing with rough clod-crushers is necessary.

Wheat should be sown on a **moist seed-bed,** but care should be taken not to harrow the surface too much, or too soon after rain, especially on 'running' land. On heavy land, water gutters should be made to carry off surplus water; if this is neglected the wheat at the bottom of the 'lands' will die out during winter.

Wheat is generally **pickled** or dressed with a solution of copper sulphate or 'bluestone' before being sown, for the prevention of certain fungoid diseases, such as bunt and smut (*see* p. 390). One pound of copper sulphate dissolved in 1 gallon of water will be sufficient to steep 4 bushels of wheat.

Subsequent Cultivation.—Wheat requires very little attention during winter. If attacked by insect pests, such as wireworm and leather-jacket, or if the land is very loose, it is advantageous to roll it, so as to consolidate the soil around the roots; but on the majority of soils, except the most friable and easily dried, it is impossible to work the roller in winter. In spring much benefit

results from rolling and harrowing. Horse-hoeing and hand-hoeing are also practised in some districts with advantage, though the drilling is sometimes so badly done that the horse-hoes cannot be worked without destroying a portion of the plant. Nevertheless, excepting upon certain soils of peculiar character, the wheat crop is greatly improved by hoeing, and the land remains cleaner subsequently, as not only are annual weeds destroyed, but seedling plants of couch and docks are killed. Hand-hoeing wheat costs from 3*s.* 6*d.* to 4*s.* 6*d.* per acre.

Often in the spring the young wheat plant turns a sickly yellow colour and appears to be going off. When this is the case a top dressing of some quickly-acting nitrogenous manure, such as nitrate of soda or sulphate of ammonia, should be applied at the rate of about 1 cwt. per acre. This will generally have the effect of restoring the colour and the vigour of the crop.

Harvesting.—Wheat should not be allowed to ripen before it is cut. When the straw immediately below the ear assumes a yellow tinge, it is time to commence cutting. If left until it is perfectly ripe, the quality of the grain is injured by the increase in the thickness of the bran (fig. 48) and a corresponding decrease of flour inside it, without gain in weight or bulk. The grain is also liable to be 'whipped' out by strong winds if the crop is allowed to stand too long. Cutting somewhat later has certain advantages, however, when the grain is to be used for seed purposes, as a thin skin is then of no advantage. The yield in these circumstances is also greater, the sample plumper, and the seed well matured. Some discretion is needed as to the degree of ripeness which the 'kernel,' or grain, is allowed to attain, for, if the weather is very hot and the straw is very thin, the sap ceases to flow upwards so early that the grain feeds but little from the straw and fails to mature; examples are not infrequently seen on thin chalk soils. On rich loams, where the straw grows stout and thick, the cutting may be commenced when the straw becomes only slightly yellow. Cutting wheat *green* has quite gone out of fashion.

Wheat is usually **cut by reaping machines**; but occasionally, in wet seasons, when the crops are storm-broken and twisted, the **scythe** or the **fagging-hook** is necessary, as the machines are liable to cut off the ears so closely that they cannot be gathered by horse-rakes, and are therefore lost. **Manual labour** is always more highly paid in harvest-time than at other seasons, and perhaps the most common practice when the work is done by the day is to double the ordinary wages. In those districts where the men receive no extra sum or bonus at Michaelmas, it is customary among farmers to pay more during harvest to the permanent hands employed on the farm. The extra wages are, in fact, a sort of retaining fee to insure a plentiful supply of workmen at that busy season. Work is often let by the piece, so that the men are paid in accordance with what they actually do. In one way or another the earnings of labourers in different districts vary from £4 to £8 per harvest month. From this it may be gathered that the cost of the different operations connected with harvesting varies very much according to custom, and what is looked upon in one locality as an excessive wage is not considered great in another. For instance, tying wheat costs in some districts 3*s*. per acre, whilst as much as 5*s*. per acre is given in others, and, in the case of badly-laid crops, 1*s*. or more is occasionally added to this. Cutting by means of a machine costs about 2*s*. per acre, more or less, according as the weather is favourable for the work: this, with 3*s*. 6*d*. for tying and stooking, brings the total cost to 5*s*. 6*d*. per acre. Mowing, tying, and stooking generally costs from 6*s*. to 10*s*. per acre; but, in some years, many farmers give as much as 20*s*. per acre where the crops are much storm-broken. By the use of the binder, cutting and tying costs from 3*s*. to 4*s*. per acre.

Wheat should not be tied when it is in a wet condition; but as it has to stand in the stook for a long time, it is not greatly injured if it is tied whilst the weeds in it are still green. The sheaves should be set up in stooks or shocks immediately after they are tied. The stooks should be composed of not more than twelve

sheaves, six on each side of the shock, and so placed that the sun may shine equally on both sides. The stooks must be arranged in such a way that whilst the butt ends of the sheaves stand well out on the ground, the ears are brought together at an acute angle, in order that the rain may shoot off them; otherwise the moisture will soak into the sheaves, and great damage will result to the grain. The practice of clubbing the sheaves into a round heap, forming a large flat surface of ears, is most injudicious, and is generally the result of laziness on the part of the men, or of carelessness on the part of the farmer.

Wheat is rarely fit for **stacking** in less than a week after it is cut, and in dull seasons it may require to be left a fortnight before it is safe to stack it. If stacked too soon it will ferment, and the grain will become mouldy, or acquire a permanent odour, which will cause the flour made from it to be unsaleable.

The carting and stacking without an elevator require a man and a lad to load, and four men to empty the carts and make the stack. They will clear from 8 to 15 acres per day, according to the size of the crop. Wheat should not be carted while the insides of the sheaves are wet, and great care should be taken that they are dry beneath the band. If the sheaves have been thoroughly dried a heavy dew need not prevent carting, nor need a slight rain put a stop to the operation.

All **stacks** should be laid on a bottom which allows the air to circulate freely under them. In building, it is necessary that the middle of the stack be kept considerably higher than the walls, as, in the process of settling, the middle, owing to the greater amount of pressure, sinks more than the outside. If the stack settles in such a way that the inner portion becomes lower than the outer, the butts of the sheaves on the external face will be higher than the ears; consequently, whenever rain falls on them it will be conducted to the middle of the stack, instead of being at once shot to the ground. After the stack has settled sufficiently—which is very little in the case of a properly built stack—it should be thatched with straw, or covered in with

one of the modern substitutes for thatch, such as corrugated iron. A well-built stack suffers little from rain even when unthatched, while one which is badly constructed often suffers considerably when it is thatched. The cost of thatching is 1*s*. per square of 100 square feet. Taking one crop with another, the harvesting on a farm is often let at about 10*s*. to 12*s*. per acre, the master finding machines, horses, and boys to drive the horses during carting.

Wheat is now all **threshed** by machinery. When an ordinary eight-horse set is employed, with an elevator (fig. 27) to lift the straw, one man is required to tend the engine, another to feed the machine, another to cut the bands, two men to throw up the sheaves, two men on the straw-stack, one to look after the corn and cavings, and one to fetch water and clear away the chaff. Boys may be employed in the place of men in the latter light jobs, but the equivalent of nine to ten men must be provided. In a day of ten hours, from eighty to one hundred sacks of corn, according to the crop and yield, should be threshed.

The modern threshing machines are made with very efficient cleaning apparatus, so that nothing but corn need be left in the sample. Owing, however, to carelessness and other causes, rubbish finds its way into the sack, and must be removed. A well-cleaned sample always sells more easily, and commands a more remunerative price, than the same sample containing impurities. Hence, in practice, it is found advisable to further clean grain, although it has been treated as well as the threshing machines are able to do it. With this object the corn is dressed or winnowed (fig. 33), or is passed through machines which perform both operations at the same time. Wheat is now sold by weight, but the standard varies very much in different markets. The weight of an imperial bushel is 63 lb., and the net weight of a quarter (8 bushels) is 504 lb. The average natural weight of a bushel is 61½ lb.

The average **yield** of wheat in Great Britain is some 30 bushels of grain to the acre, although good crops may

reach as much as 50 bushels, or more. The yield of straw will vary from 30 to 35 cwt.

OATS.—Oats will grow on most soils provided there is sufficient moisture; the question of climate being really more important for their successful growth than that of soil. They are well suited to the damp climates of the north of England and Scotland, as they require less warmth and sunshine than wheat or barley.

In the dry districts of the south they prefer the stiffer soils, but in wet climates the best results are obtained on the lighter loams. Oats may also be grown at considerable elevations above the sea level, and they are generally the first corn crop taken after breaking up grass-land.

Seeding.—Oats, as a corn crop, are almost always sown in the spring, but in a few light-land districts they are popular as an autumn-sown crop. If sown in the autumn, they should be put in early, so as to become well established before the frosts begin. The spring-sown oats, which may be taken after roots, leys, potatoes, and other crops, should likewise be seeded early. After the opening of the year, no opportunity when a fitting seed-bed can be obtained should be missed. It is advisable to put the seed in on a well-prepared seed-bed, but, if the land is judiciously worked, it is not absolutely necessary that the finest tilths should be made, as the plant is robust, and if the surface should be a little coarse the fault may generally be corrected by subsequent harrowing and rolling. Hence, there is nothing of a very special nature in the preparation of the seed-bed for oats.

Seeding may be continued late in the season, although the earlier-sown crops almost invariably yield best; but a fair crop of oats may be obtained when it would be too late to sow barley with the expectation of obtaining a paying crop. Thus, when the root crop is not cleared by sheep until too late for barley, quickly maturing varieties of oats may be profitably sown. Oats may be either sown broadcast, or drilled. Drilling, of course, permits of better opportunities of cleaning the

crop subsequently, and on land troubled with annual weeds this is of much importance.

The **after-cultivation** of oats is similar to that of wheat, and if the land is loose and open after planting it may be advisable to harrow and roll just when the young plant is coming through.

Harvesting.—Oats should not be allowed to become thoroughly ripe before cutting; in fact, they are best cut as soon as the grain is fairly filled, as the latter has great power of absorbing nutriment from the stout straw characteristic of the crop. It is advisable to cut oats when there is a light yellow shade noticeable throughout the field; the straw below the neck will still be green. The warning given previously in reference to the early cutting of wheat on poor land is applicable to oats. The crop is cut, sheaved, and stooked in the same way as wheat. Oats, however, require to be in the stook for a greater length of time than wheat, for they retain moisture longer, and readily ferment when stacked. Fermented oats are distinguished from others by their brown skins, and are not so valuable because they have an injurious effect on animals which consume them. The straw makes an exceedingly useful fodder, especially when chaffed.

The yield of oats may vary from 40 to 60 bushels of grain per acre, according to the crop, and the straw from 30 cwt. upwards.

BARLEY.—This cereal requires more careful cultivation than any of the other cereal or corn crops. It is so very necessary that a uniform sample at harvest should be obtained, that care must be exercised in every operation before and during the growth of the crop. Barley is grown more in England than in other parts of the United Kingdom, and climate and season play an important part in determining the value of the crop. The dry climate of the south and east of England appears to be more particularly adapted to the production of first-rate malting samples, and the crop seems to give the best results on the lighter soils, especially those on the limestone formations. Strong clay soils and soils of a peaty nature are not so well adapted to the growth

of barley. Barley is most commonly taken after roots; but, as it is found that after a heavy crop of roots has been fed on the land the soil is too high in condition, and is consequently likely to produce an over-rapid and unreliable growth, and a coarse, uneven sample of grain, unfitted for malting purposes, it has become the practice with many farmers to first grow a crop of wheat after the roots. Barley grown **upon a wheat stubble** generally yields a far superior sample to that obtained after roots fed by sheep, and, since wheat has been so cheap, barley often follows 'seeds' in place of wheat. The former practice allows the high condition of the soil to be reduced, and the inequalities in the feeding-off of the roots to be rectified, before a barley crop is taken. This is good farming so far as it can be adopted; but the extent to which the system is applicable is limited, because wheat is not often a paying crop when planted in the spring, and the land on which it is grown must necessarily be that from which the roots are fed off before December. Oats may be substituted upon the later-fed-off ground with advantage. Barley is also grown **after potatoes,** and occasionally after tilths made during autumn, which have been produced under autumn cultivation.

Whatever the previous crop, it is very necessary that **a thorough tilth** should be prepared. The best tilths are those which are obtained by the soil having been exposed in the furrow to the effects of frost during winter, hence the land should be turned as early as circumstances will permit. It is useless—in fact, harmful—to stir this land in winter, and it should be left alone on all occasions except the special one afforded during moderate frost, when, if turned, the furrow is undoubtedly very much mellowed. After roots, unless the land has been badly trodden and 'poached' whilst being fed off by sheep, so that the sheep have sunk into the depths of the fallow ploughing, the ploughing for barley should not exceed more than 3 to 4 inches in depth. Barley requires a 'kind' seed-bed, but it is essential that it should also have a firm hold for its roots; and this is not obtained when a deep light tilth

is prepared, as is not uncommonly the case. The tilth must be light, free from excessive moisture, and must be obtained without puddling the ground below the immediate surface, or the free percolation of rain-water will be impeded, and though to outward appearances there may be reason to expect a healthy growth, an unsatisfactory crop will result. If there is time in the spring, the land may be ploughed again; but this is not often convenient, and it is more common to work the land to a tilth by means of repeated stirrings and harrowings, using the implements in the usual order of scarifier, drag-harrow, harrow, and roller, following up the next workings by dropping the heavier implements, until, as the time for seeding approaches, the lighter harrows only are used.

Seeding.—Barley should be **drilled,** as it is more evenly deposited in the land than when it is sown broadcast on the surface and harrowed in to unequal depths. When the seeding is effected at different depths the germination is uneven, as some of the seed may not reach the moisture, while other falls to the proper depth, and some goes too deeply. A crop which comes up unevenly makes a bad start towards producing a uniform sample of grain, suitable for malting. The seed should be harrowed in so as to be lightly covered, and if the soil is not left sufficiently 'kind,' fine, and mellow on the surface, this must be rectified by harrowing or rolling as occasion permits, both before and after the plant is above ground.

After Cultivation.—Barley may be rolled or harrowed with advantage, provided the land is dry, at the time that the blade is appearing above ground; and again when the plant is about 3 inches high, and the second strong shoot is commencing to grow. If the work is done at other periods, there is danger of the plant being smothered. In some districts barley is never hoed, but, as in the case of wheat, if the work is done under favourable circumstances it proves profitable.

Harvesting.—Barley should not be cut until it is fully ripe, or a uniformly germinating sample for malting will not be obtained. The straw should be white, and the

ear should hang on one side, becoming 'sickle-headed,' a term used to denote that the ear has curved downwards. The grain should be hard, and the skin covering it should be wrinkled into a fine network. If the skin is smooth, or contains colour, it will not attain the clear, light shade so necessary for a perfect sample of malting barley. Barley is considered to be benefited by being exposed to alternate sunshine and light rain or dew for two or three days after cutting, as the grain becomes more mellow and improves in colour. For this reason it is held preferable to cut barley by the scythe if good weather can be ensured, for by turning it twice the whole of the 'kernels' become bleached to the same extent, thus avoiding the 'two colours' which maltsters complain that they get in a sample which has been sheaved, thereby preventing the inner portion of the sheaves from benefiting from the mellowing effect of genial weather after the crop is cut. In the north of England, however, both opinion and practice are the reverse.

Barley is fit to **stack** much sooner when it lies loosely than when bound in sheaves; especially is this the case when there is much green material, such as clover or weeds, present, as the sun and wind have a free opportunity to exercise their influence, which is impossible in a tightly bound sheaf. Much smaller loss also is believed to result when the scythe is used in cutting the crop, as there need be no ears cut off short on a fairly upstanding crop; whereas, with a machine, there are always dropping ears which are snipped off and lost. Here, again, however, local opinion is at variance, for North Country farmers consider that there is more waste with the scythe than with the machine. Many farmers strongly support the custom of tying barley, and a great point in favour of the practice is that, when the barley is bound, there is much less trouble to cart, stack, and thresh it. But it is not uncommon, during wet periods, for the sheaves to become saturated, and it is then found necessary to untie them, and spread them out to dry. The flaggy nature of the straw is much more likely to cause the water to be absorbed than is the case with

wheat; therefore the fact that the sheaves are stooked is not sufficient to guarantee the safety of the crop. A short supply of labour has compelled many farmers to use the binder; and this is now the general method of cutting in most districts.

It seldom happens that barley comes out of a stack in the same condition as it went in; it is usually better or worse. If carted in good condition it improves; if stacked when damp it deteriorates. It is therefore very necessary to cart it when in good condition. As it readily spoils, it should be stacked whenever an opportunity should offer. As wheat is much less likely to be injured in the field, the carting of wheat should always give way to the carting of barley when the weather is favourable. Barley stacks should be thatched as soon as possible, as the flaggy straw prevents the water from running off the roof, where it soaks in and does much damage. Care should be taken, during both stacking and threshing, that inferior barley does not get mixed with that which is bright and good, for a very small quantity of bad barley is capable of deteriorating a large bulk to the extent of many shillings per quarter. Barley, of all corn, requires to be well prepared for market, and, in addition to the ordinary winnowing, it is advisable to put it over the 'Boby' screen. The weight of an imperial bushel is 56 lb., which is about 2 lb. in excess of the average natural weight.

The average **yield** of barley is from 32 to 40 bushels of grain, and some 20 cwt. of straw per acre.

Rye.—This cereal is not grown to any great extent for its grain in this country, but is sometimes used as a forage crop. It will grow in late districts and on poor soils unfavourable to the cultivation of other corn crops. In the few places where it is grown as a grain crop it takes the place of wheat in the rotation, but where cultivated as a forage crop it generally comes in as a catch crop before roots.

The **cultivation** is similar to that of wheat, the land being ploughed, and a seed-bed firm underneath and not too fine on the surface being obtained. When grown for forage, it generally follows a corn crop, the stubble of

which is dunged and ploughed, and then worked down into a seed-bed with the drags and harrows. In either case it is, as a rule, sown in autumn, the seed being drilled at the rate of 2 to 3 bushels per acre.

When consumed as a forage crop it has to be mown or eaten off in good time in the spring before the ear appears, for as soon as it gets at all old it becomes coarse and unpalatable to stock.

When harvested as a corn crop it is generally ripe before the other cereals—about the end of July or beginning of August—and cutting and subsequent operations in securing the crop are the same as in the case of wheat.

The average yield of grain is from 24 to 32 bushels, and straw 30 to 40 cwt. per acre.

PULSE CROPS

Beans.—These are sometimes sown in the autumn, and are then known as 'winter beans,' as the varieties used are hardy, and are able to withstand the cold of a moderately severe winter, though they are sometimes killed, especially if the land be wet from want of drainage. Winter beans are fit for harvesting earlier than spring beans, and are less liable to injury from the green and black 'flies' (aphides), which do much harm to late beans. As the 'flies' do not, as a rule, appear until July, it is a decided advantage for the beans to reach a stage in which they are past injury.

Beans do best on the stronger soils, especially those containing a fair percentage of lime; in fact, beans, as in the case of wheat, will grow on the heaviest clays in this country. The light soils in the drier districts are not so well adapted to their growth, and the crop is often disappointing in these cases.

Beans are rather an uncertain crop, and liable to be affected by severe frost. They are, therefore, more suited to the genial climate of the southern portion of Great Britain. On heavy land beans are sometimes taken as a cleaning crop in the place of roots, and the

though not so valuable as pea straw, is nutritious, and the upper portion is very palatable.

The **yield** of the bean crop is from 30 to 40 bushels of grain, and some 25 to 30 cwt. of haulm or straw per acre.

PEAS.—This crop grows best on the lighter descriptions of soils, such as the sands, gravels, and freer-working loams, especially when these soils contain a fair percentage of lime.

Peas are occasionally drilled in the autumn, but the practice does not gain ground, most growers finding that the crop does as well when sown in the spring. Peas are, as a rule, **planted on a barley stubble** which is broken up in the autumn, very commonly after the conclusion of the wheat-seeding. It is generally found that peas flourish best on a stale furrow, and that beans do best on a comparatively new furrow; therefore in ploughing in the autumn, the pea land should be turned over first. Peas are sown at different periods, according to the varieties. The field-pea, of which there are several sorts, distinguished by bearing a blue blossom, should be sown as early as possible in the spring. The white peas and round blues, such as the Prussian blues, all of which bear white flowers, should be got in next—some time during February or March. The soft, wrinkled peas, grown for culinary purposes, should not be sown too early in open field culture, and except for very early picking should not be put in until April, or, being tender, they will probably be injured by frost.

Peas require a finely-prepared seed-bed, and should not be drilled when the land is at all sticky; the more tender varieties require comparatively better seed-beds than do the hardier kinds. It is rarely advisable to plough pea land a second time, but it should not be trampled on while wet below the surface, or a fine under-tilth will not be obtained. It is better to delay the seeding than to puddle the ground by trampling it too soon. If the land is harsh and unkind it should be stirred first with a scuffler, then with the drag-harrows, then with light harrows, and, if necessary, reduced by rollers. If the land is in a mellow state the drag-harrows

will be sufficiently heavy to stir it, and the lighter harrows will perfect the tilth. The seed should be drilled whilst the land is friable, and covered in by sufficient harrowings to render the peas secure from birds.

After Cultivation.—Peas should be harrowed just as the shoot begins to peep above the ground. If used at this stage the harrow destroys many small weeds, and opens the soil immediately around the individual plants with beneficial effect. The crop should be harrowed and rolled when about 3 inches high, whilst hand-hoeing should be commenced early, and continued until the rows meet, and the hoes can no longer be worked.

Harvesting.—Peas should not allowed to ripen before being cut, or many of the pods burst, and the peas fall out during the turnings to which it is necessary to subject them while in the field. It is sufficient that the haulm should be yellow, and the pods tough and likewise of a yellow colour. All peas should be cut with a pea-hook (p. 97), and should be worked up during the operation into small heaps or 'wads.' If the peas are mown by a scythe, the pods are liable to be cut open, or to be left on the ground on the base of the haulm. Pea-hooking costs from 5*s.* to 8*s.* per acre. After the crop has lain in wads until these have become somewhat dried, the heaps must be turned over. From time to time they must again be turned, especially in wet or dull weather, when, if not turned, they become mouldy both in the middle and at the bottom of the wads. If carted before they are in fit condition, they become mouldy in the stack. It is particularly necessary that the softer or wrinkled varieties should be stacked in good condition, or a very large proportion of the peas will be spoilt. When they are being threshed, care must be taken that they are not split, or they will be useless for seed purposes. It is often necessary, especially with the softer varieties, to take off the steel bar from the beaters to avoid too hard hitting. A sack of peas (4 bushels) should weigh 19 stones (= 266 lb.). Pea haulm is the most valuable of the straw fodders, and is particularly suitable, when chaffed or steamed, for dairy cows and ewes.

The yield of grain is from 30 to 40 bushels per acre, together with some 25 cwt. of straw or haulm.

ROOT CROPS

Preparation of the Land for Root Crops.—This occupies to a greater or less extent nearly every season of the year, although the time at which the work is most actively carried on is during the seasons of autumn cultivation (immediately after harvest), winter ploughing, and spring ploughing, to which may be added early summer stirrings, when the actual seed-beds are prepared. (*See* chapter vii. on Tillage.)

The process of cleaning is much more easily effected when the first stirring or ploughing is done on dry land in dry weather. The comminution of the land is very difficult when it is in a wet condition, and the endeavour in bringing land to a tilth is to work it so that none of the operations cause any portion of it to 'puddle' or become annealed. When land is trodden upon or worked while it is in a wet or sticky condition it dries into harsh clods, and these clods, when reduced by force, as by rollers or harrows, do not fall down into a soft, mellow powder, but into small, angular particles which have not the power of retaining moisture during droughty periods.

A special effort should always be made to prepare a piece of land for the mangel crop, for mangel is best sown early in the spring, at a time when the perfect tilth required is often difficult to obtain. The most approved method of preparing the land is to choose a piece which is nearly, if not quite clean, and to fork out any small pieces of couch, so that the work in the spring may be directed solely to the obtaining of a tilth, without any hindrance being caused by cleaning. After the couching, the land should be dunged with long dung, and turned over in dry weather, when good working in the spring will be ensured.

It is not advisable to hinder the spring seeding of the cereal crops by employing the horses on the fallows;

consequently, until the greater portion of the corn is sown, it is not usual to do much to the fallows. If, however, the work is forward, the fallowing operations will be made more easy if the land is ploughed or scuffled in March, provided the weather is favourable. Steam cultivators and steam drag-harrows are particularly valuable at this season, as by their use the greatest advantage from a short spell of fine drying weather can be obtained, inasmuch as a large tract can be worked. By using these heavy implements first, the horse-work is greatly lightened, as the most severe strain on the horses occurs during the first moving of the land. As the season progresses, the cleaning and tilth-preparing operations should proceed, and, if the dung has not been got on during winter and the earlier part of spring, it should be carted on whenever an opportunity should offer. Dung for roots, when applied in the spring, should always be put on in a rotten condition, as the crop will speedily need to make use of it, so that there will be little possibility of its fertilizing ingredients being washed out before the plant can take them up.

The method of preparing a tilth on the root fallows has already been discussed in the chapter on Tillage, but a few further remarks on the subject may here be added.

The preparation of the land for the root crop must be carried out in such a manner as to result in the production of a deep mellow tilth. Where the land permits it, the furrow should be ploughed at least 6 inches deep, and the whole of the land which is moved should be made into a friable tilth. If the land is wet, and in a moist, sticky condition below the surface, a proper tilth cannot be obtained unless the under side of the furrow is brought to the surface to be subjected to the disintegrating effect of the weather, the chief factors of which—rain, wind, sunshine, and frost—all help to shatter the clods. If heavy land is turned up when wet, and great care is not exercised in its management, it is liable to aggregate into 'nubbly' brick-like clods, unless there are a considerable number of alternating frosts and small showers to prevent this. At the same

time, if circumstances permit, and the clods become quite dry, then, on being rained upon, they will lose their adhesive properties, and the particles will fall down to a fine mould. As it is uncertain, however, when the rain will fall, there is great risk in this latter process, as the season may become too far advanced before advantage can be taken of it, and the crop may not be sown soon enough to afford as large a yield as if sown earlier. The light frosts which often occur during spring are most useful, and should be utilized on all occasions. When frosts are likely to take place, it is advisable to stir the surface with harrows, so that a moist side of the clod may be brought under the influence of the cold; and when the clods are in a frosted condition, which may perhaps only last an hour or two after sunrise, a special effort should be made to move them, as they will break much more easily for being stirred while frozen.

There is a large breadth of swedes and turnips sown in the north of England, where the land is not again touched by the plough, after the good stubble furrow which has been turned over in autumn or early winter. The land is allowed to become thoroughly dry, and is then broken up by grubbers and harrows to the depth of the winter furrow. Thus the friable soil, which has been exposed to the action of frost, is kept at the surface to *braird* the turnips (*i.e.*, to promote the growth of the seedling plants), whilst the moisture is likewise retained in a dry season.

The cleaning and tilth-preparing operations for roots are carried out on practically the same lines as those recommended for autumn cultivation. As, however, fine seed-beds are required, the final operations must be performed more carefully and delicately, as there are fewer opportunities of correcting errors. Great care must be taken not to plough during wet weather, nor to harrow the land while it is wet or immediately before rain, or it will run together, forming a paste on the surface, which, on drying, will set like cement, and destroy the tilthy properties of the soil, whilst a large amount of fresh work, entailing a corresponding loss

of time, will have to be done. It is impossible to convey on paper the circumstances under which it is advisable to have the land harrowed down on the one hand, or rolled down on the other, when leaving it. Trifling conditions with regard to moisture, the amount of work put into the land, the weather present and prospective, and various other circumstances, have to be taken into consideration, and can only be decided upon by observation in the field at the time. Many crops of corn and of roots are seriously reduced in yield owing to the final working being done by the harrow instead of by the roller, and *vice versâ*.

The **general principles** to be observed are that it is injudicious to leave the land rolled down when it is moist, or when rain is expected before the surface has become 'hazelled,' or dried into the light-brown colour peculiar to land freshly stirred. It is unsafe to harrow it while very wet, as it can hardly fail to set hard if it dries quickly. If the land is dry and puffy, so that moisture may escape before seeding is commenced, and before the moisture which would ascend from below by capillarity has had an opportunity of rising, it should be rolled in preference to harrowing. A good tilth retains moisture. If a tilth is fine it is able to draw up a large amount of water from below, but it must be sufficiently compressed for the particles of mould to touch one another on all sides, or the capillarity is weak; therefore, very light dry tilths must be rolled. But if a tilth is consolidated while wet, then, instead of the particles being brought close together, so as to assist the upward flow of moisture, these particles will be, as it were, driven in amongst one another, forming a tough paste and destroying the capillarity, so that the soil on the immediate surface will receive no moisture from below. As, moreover, the soil will be losing it by evaporation from above, the moisture will so effectually disappear, that any seed sown will be unable to germinate until rain falls. Want of judgment in the management of the final workings is responsible for the greater portion of the losses of plant in root crops, as well as the indifferent growth of the plant

when up. The knowledge required can only be obtained by constantly witnessing, or taking part in, the operations themselves. It is considerations of this kind which, though apparently trifling, make all the difference between successful and unprofitable farming.

SEEDING OF ROOT CROPS.—Root crops are sown on the ridge or on the flat, according to the district and climate. The ridge system is that in which the land is laid up in ridges 2 feet 3 inches or more apart, and the seed is sown along the top of each ridge. This is practised chiefly in wet districts or on heavy land, the ridge shooting off excessive moisture, which would otherwise be injurious to the growth of the crop. The flat system is carried out in dry districts, and on light dry soils. The moisture is retained longer during droughts than when the land is laid up in ridges into which the sun can penetrate. It is usual to put the dung on the land at some time previous to the final preparations for the seed-bed, when the roots are to be drilled on the flat, so that it may become incorporated with the soil; but, in the case of the ridged land, dung is applied just before the final ploughing. The land, already worked to a tilth, is ridged, and the dung is placed in the furrows; the ridge is then split back over the dung, thus forming a new ridge upon it, and on this the seed is afterwards drilled.

MANGEL WURZEL. — This is the first root crop drilled. Where the land is free from annual weeds, the seeding may be commenced much earlier than if these pests are abundant. If this freedom from weeds has not been secured—and it very rarely is—it frequently happens, during cold seasons, that the weeds grow more freely than the mangel, and the crop becomes so foul that it is impossible to clean it without cutting up the plants, so that it becomes necessary to re-sow the field. Therefore, though the first week in April may be looked upon as a good season for drilling mangel in one district, equally good farmers in another district would not put the seed in before the first or second week in May. Mangel does best on strong loams, though with lavish manuring it can be made to grow on almost any

soil. It is a very difficult crop to raise, because of the trouble involved in getting a full plant (p. 216). For this reason a little swede seed is frequently mixed with the mangel seed; if the mangel is a full plant the swedes are taken out, otherwise they are left to occupy the gaps. The transplanting of small-topped kohl rabi is a still better means of filling up such vacancies.

A perfect tilth is necessary, and this when dried should be consolidated so that the seed can be deposited at a uniform depth. If the tilth is loose, the moisture does not rise sufficiently near the surface to promote germination of the seed, which must not be deposited at a depth greater than from ½ inch to 1 inch in the soil; otherwise it does not come up at all. The final working at the time of drilling must be regulated by the dryness of the tilth, and the probabilities of rain. The seed is sown either without manure, with liquid manure, or with dry-compost manure, as, in fact, are the seeds of all the root crops.

Although mangels and turnips resemble one another as far as the cultivation of the ground is concerned at a preparation for the crop, they differ considerably as regards their **manurial requirements.** The mangel may be described as a gross feeding plant, requiring a liberal all-round manuring, containing the three essential ingredients of plant-food liable to run short in the soil—viz., nitrogen, phosphoric acid, and potash. It is therefore generally grown with heavy dressings of farmyard manure, to which additional supplies of artificials are frequently added. Mangels possess a strong tap-root, which strikes deeply into the soil, so that they are able to keep themselves fairly well supplied with mineral ingredients during the growing period, but they have difficulty in obtaining sufficient supplies of nitrogen when making rapid growth. In these circumstances it is the custom to apply some quickly-acting nitrogenous manure, such as nitrate of soda, at the rate of 1 to 3 cwt. per acre in two or three top dressings at short intervals. Artificial additions of phosphates and potash are also often added at the time of sowing the crop, and although the effect of these is not so marked

as in the case of a nitrogenous manure, still it is a wise precaution on certain soils when bulky crops are being grown. On some land a dressing of common salt will be found to have a beneficial effect, and in these cases it will be unnecessary to use any extra supplies of potash.

Manurial experiments carried out in many counties during the last few years tend to show that moderate dressings of dung—say, 12 tons to the acre—can be profitably supplemented with a suitable mixture of artificial manures in growing mangels.

In a number of trials carried out on various soils in Gloucestershire the following mixture of artificials in addition to dung gave the most profitable result—viz., 4 cwt. of superphosphate of lime, 1 cwt. of sulphate of ammonia, 4 cwt. of common salt applied at the time of sowing, and 1¼ cwt. of nitrate of soda applied in two top dressings after the crop was up. In most cases it would be better to apply the common salt a few weeks prior to drilling. In sowing mangel, the rows are drilled at a width of 2 feet 3 inches or more on the ridge, and from 18 inches to 30 inches on the flat, according to the soil and its preparation.

SWEDES.—These are the most valuable variety of the turnip family. The preparation for this crop is chiefly made in spring, and though the seeding commences in the early part of May in some districts, it is not begun until the second week in June, or even later, in many others. This is because the early-sown swedes are specially liable to attacks of mildew, when grown on soils which soon become parched in seasons of hot, dry weather. If swedes have grown rapidly, and then receive a sudden check, the mildew attacks them, and may utterly destroy them. The early-sown swedes suffer most in this respect, as they are less vigorous. When land is ridged, it is inconvenient to make the ridges of less width than about 2 feet 3 inches; therefore it may always be understood that crops of roots drilled on the ridge are drilled that distance or more apart. On the flat, however, it is not uncommon to drill them as near as 18 inches from row to row, though 2 feet is the most common distance.

Swedes and turnips differ from mangels in being shallow-rooted, and therefore require their food in a soluble form near the surface. Phosphoric acid is the ingredient they have the most difficulty in obtaining from the soil, so artificial mixtures used for the swede crop should consist largely of phosphates in some form or other.

Good crops of swedes and turnips can be grown with farmyard manure alone, but better results are generally obtained by using a moderate dressing of dung supplemented with some quickly-acting phosphatic manure, such as superphosphate of lime. Such a dressing would consist of some 10 tons of dung per acre, put on beforehand, together with 3 to 4 cwt. of superphosphate sown at the time of drilling. It is to be remembered, however, that in the north of England larger quantities of artificial manure are used for the root crop than in the south. In some arable districts, such as the Cotswold Hills, many acres of swedes and turnips are grown with artificials only, without any dung, and in such cases the usual dressing consists of some 4 cwt. of superphosphate per acre, together with ½ to 1 cwt. of nitrate of soda or sulphate of ammonia. Where the soil is naturally deficient in potash, from 2 to 3 cwt. of kainit may also be allowed in addition.

Turnips.—There are several distinct varieties of turnips, and there are almost innumerable selections of these varieties, which are very similar in everything but their names. Among the most commonly grown sorts (*see* p. 182) are the Purple-top Mammoth, Pomeranian White Globe, Imperial Green Globe, Hardy Green Round, Lincolnshire Red Globe, Early Stone, Green-top Aberdeen, Purple-top Aberdeen, All the Year Round, Yellow Tankard, Favourite, Early Six-weeks, etc. These can be sown so as to provide food from July to Christmas or later, if advantage is taken of the early maturing and frost-resisting properties possessed by individual varieties. If sown very late in the summer, they will resist frost, and throw up sprouts in the spring, which are very valuable as sheep or lamb feed in February and March. A good tilth is necessary, and the earliest

varieties may be put in during April; but, for a main crop, May and June are usually the best months. Seeding may continue on the bastard fallows, and after green crops generally, until the middle or end of August. The stubble turnips, if sown at the latter date, are fit for feeding in the autumn. It is not an uncommon practice to sow the stubble turnips broadcast, but all early-sown varieties should be drilled, in order to allow proper opportunities for hand-hoeing and horse-hoeing.

CARROTS.—These roots grow best on light soils free from stones. If grown on heavy soils they are troublesome to dig up, and so much earth adheres to them that washing becomes tedious and expensive. As the young plants have very small tops, the crop is not suited to weedy land, for in cold seasons the weeds overgrow the carrots, so that it is practically impossible to separate them. A few oats are sometimes mixed with the carrot seed before drilling, as they help to show up the rows after germination. A fine tilth, prepared by the land being ploughed and dunged during autumn, and well stirred just before seeding, is necessary; and the seed should be drilled, in March or April, in rows from 12 to 18 inches apart. About 6 to 8 lbs. of seed per acre is required, and before sowing it should be well rubbed and mixed with dry sand or ashes, so that it will not clog in the drill, but will fall freely into the drill-rows. It should be harrowed in with light harrows, and not covered with more than an inch of soil. Carrots are particularly valuable as food for horses and dairy stock.

In some districts a small quantity of carrot seed is sown with the mangel crop, as the carrot will often stand where the mangel fails, and it grows well in association with mangel.

PARSNIPS.—These roots grow more freely than carrots, and, though they require good preparation of the soil, their broader tops are better able to grow away from weeds. The seed should be drilled in February and March, about 6 to 8 lb. per acre, in rows a foot apart.

Much of the information which has been given in this section is presented in a condensed form in Table XXV., pp. 342 and 343.

SUBSEQUENT CULTIVATION OF ROOTS.—Roots require much attention after the seed is drilled. The chief operations are hoeing and horse-hoeing. The horse-hoe should be set to work as soon as the rows of young plants afford a guide for steering; and, in cases where the drill-rows have not been harrowed out, horse-hoeing may with great advantage be commenced before the plants are visible. It is, of course, necessary to set the hoes so that the small plants shall not be smothered. For this purpose hoes, which are so attached to the stem or standard that the mould is not thrown on to the rows, must be used. Although many specially formed hoes have been introduced to turn the mould inwards from the plant-rows, there is nothing superior to a broad V-flange hoe, with the stem placed some distance from the row, as even when the land is wet and there is loose straw or litter lying upon it, the hoe does not block. The horse-hoes should be put to work as frequently as possible, until the roots get so big that the horses cannot walk along the rows without injuring them.

The manual labour consists of flat-hoeing—often dispensed with in the case of swedes and turnips—with a broad hoe alongside the rows, to clean such places as the horse-hoe misses, and of 'singling,' to set the plants out at regular distances, and to separate the plants so that there shall not be more than one standing together. Singling should commence when the plants have a width of about 3 or 4 inches across the leaves. The operation is rarely done perfectly at the first attempt, and it is usual for it to be done twice. The cost of the three manual operations varies from 10*s*. to 12*s*. per acre, according to the width between the rows. Where the rows are placed about 18 inches apart, the plants may be left from 14 to 16 inches from centre to centre; on widths of 2 feet 3 inches, a space of 11 inches is sufficient. In some localities, roots are hoed into bunches, and afterwards singled by hand by women and children.

HARVESTING OF ROOTS.—Swedes are got up in the autumn for storage in the field where they were grown,

Table XXV.— Characters of the Seed of the Common Farm Crops.

Seed.	Signs of Quality.	Weight per Bushel.	Quantity Sown per Acre.	Most Injurious Impurities.	Time of Sowing.
Wheat ...	Bright thin skin; freedom from smell; plump grain; the 'gutter' or groove well filled in. Colour, red or white according to variety; dryness	63 lb.	From 5 pecks on old tilths to from 8 to 12 pecks on leys according to season of seeding	Seeds of wild oats, ranunculus, goosegrass, charlock, wild onions	Middle of Sept. to end of Nov., occasionally in the spring.
Barley ...	Thin wrinkled skin; grain not shrunk, but plump, with small fine ends; pale white to light golden colour; freedom from smell; dryness	54 to 56 lb.	8 to 12 pecks	Charlock (easily separated from all cereals), wild oats	Feb. to April; occasionally in autumn, when the winter (6-rowed) variety is sown.
Oats ...	Thin skin, and plump grain; colour black or white—not brown, which indicates heating at some period	40 lb. and upwards	10 to 16 pecks	Wild oats, goosegrass, charlock	Feb. to April; occasionally in autumn, when the winter variety is sown.
Peas ...	Dryness, and full size of the variety; colours white, blue, brown and mottled; black ones have been subjected to wet in field or stack, and are useless	64 to 65 lb.	8 to 12 pecks	Easily cleaned	Field peas, Jan. and Feb.; white peas, Feb. and March; wrinkled peas, March and April.
Beans ...	Colour light brown; no black ones; no smell; hardness	64 to 65 lb.	8 to 12 pecks	Easily cleaned	Sept. and Oct. and end of Jan. to March.
Red Clover and Cow-grass	Large proportion of purple seeds; no dull brown seeds, as they are dead	65 lb.	12 to 16 lb.	Docks, plantain, dodder	April to end of May.

Alsike ...	Large proportion of dark green seeds; some light green met with in the best samples; no brown ones permissible	65 lb	12 to 14 lb.	Docks, plantain, sorrel, shepherd's purse, geranium	April to end of May.
White Clover	Light golden colour; very light ones weak in germination; brown ones dead	65 lb.	12 to 14 lb.	Docks, plantain sorrel, shepherd's purse, geranium	April to end of May.
Crimson Clover, or Trifolium	Light brown colour	65 lb.	20 to 28 lb.	Docks and plantain, easily cleaned	Aug. and Sept.
Trefoil ...	Light brown colour	65 lb.	12 to 16 lb.	Rarely unclean.	April to end of May
Sainfoin ...	In husk (unmilled) or shelled (milled)	In husk 20 lb. Shelled 62 lb.	In husk 4 to 5 bush. Shelled 56 lb	Burnet, docks	April to end of May.
Lucerne ...	No brown seeds	62 lb.	20 to 28 lb.	Trefoil	April and May.
Vetches ...	Dryness; freedom from black seeds	64 lb.	10 to 14 pecks.	Small peas	Aug. to Oct. and Feb. to May
Rye... ...	Dryness	54 lb.	8 to 16 pecks.	—	Aug., Sept., and Oct.
Cabbages, Turnips, and Swedes	Dryness; freedom from mouldiness	52 lb.	2 to 4 lb.	Charlock	March to Aug., according to variety.
Mangel ...	Should germinate at least 120 per cent. (*see* page 216)	21 lb.	6 to 8 lb.	Coarse rough seeds.	April and May.
Parsnips ...	Dryness	17 lb	6 to 8 lb.	—	Feb. and March
Carrots ...	Dryness. Not compact, as it may have heated	Not recognised	8 to 10 lb.	Light rough seeds, such as goose-grass	Feb. to April
Potatoes ...	Firmness; tubers free from dry rot, and not too much sprouted ...	56 lb.	12 to 15 cwt.	—	March and April.

or they are carted to the homestead. Pulling up and topping, and throwing the swedes into heaps—the terminal roots should not be cut off—costs 6*s*. 6*d*. to 8*s*. per acre. Covering the heaps in the field costs from 1*s*. to 1*s*. 6*d*. per acre in addition. The manual cost of carting off the roots is 1*s*. to 1*s*. 6*d*., according to the weight of the crops. These prices are somewhat exceeded in the north of England, where wages are high. When stored, the roots should be carefully covered with a layer of straw several inches in thickness, and over this a layer of earth some few inches deep should be placed to keep out wet.

The **mangel** crop is harvested some time in October or early November, when the leaves turn yellow, as it is very susceptible to frost. The roots should be injured as little as possible in lifting to prevent bleeding, and the tops are preferably twisted off. After remaining a day or two on the surface to dry, they are carted to the pit or clamp, where they are carefully stacked together, and then covered first with a layer of straw and then with a layer of earth to protect them from the weather during the winter. A ventilating shaft, consisting of a bunch of straw or a drain-pipe, should be inserted at a distance of every six or eight yards.

Turnips are not usually stored, as, being soft, they are easily gnawed by sheep. When required for cattle they are pulled in the same manner as swedes.

Carrots must be dug with a fork, and stored in a similar manner to swedes.

Parsnips may be left in the land until required, as they withstand severe frost. They, however, must also be dug.

CRUCIFEROUS FORAGE CROPS

Rape.—This is very similar in its management to turnips. Occasionally a small area is sown in March to provide early sheep-keep in July. This is generally left, after feeding, to produce a second crop in spring. There are two varieties, the Dwarf and the Giant. The Dwarf

is usually grown on thin chalk and other light soils; the Giant is more commonly grown in the Fens, where it is sown broadcast or drilled in June, and fed off in September. The greater portion of the Dwarf rape is grown on land which has carried an autumn-sown catch-crop, and is drilled in May and June, at the rate of about 5 lb. per acre, in rows 15 inches apart.

Kohl rabi, Thousand-headed Kale, and Red and Green Cabbages.—These all belong to the same family, and are a very valuable addition to the green forage crops of the farm. The chief advantages they possess over turnips are that they are not so liable to turnip-sickness and allied diseases, they are less affected by drought and frost, they are very nutritious and rarely upset the health of young animals, and they may be eaten at any stage of their growth with impunity. They also not only stand transplanting, but grow more freely as a consequence, thus affording longer time for the fallowing operations. Being in the first place grown in small compact seed-beds, they are more under the control of the grower, who is able to defend them from insect attacks with greater success.

Transplanting.—When cabbage, thousand-headed kale, and kohl rabi are raised in seed-beds, they may be transplanted at various times, so that a supply of green fodder is available without intermission throughout the year. The seed-beds should be sown in March, April, and May to produce plants for transplanting through summer, and in August for autumn and spring transplanting. Kohl rabi should be grown in the spring seed-bed only, the other varieties may be grown in the autumn seed-bed also. By transplanting cabbages and kale from the autumn beds, a supply of green food may be relied upon to be fit for feeding from July to Christmas. Kohl rabi from the spring beds, transplanted in May and June, is fit for feeding from December to March; kale transplanted in summer is at its best from March to June. The cabbage tribe flourishes particularly well on heavy land. The seed-beds should be carefully prepared, as a fine tilth is necessary, and the seed should be harrowed or raked in lightly.

When plants are transplanted they are set out at various distances, according to the land and the variety of plant. Small early cabbages may be placed out at a distance of 2 feet apart in each direction; drumheads and red cabbages are best planted from 2 feet 6 inches to 3 feet apart.

The above crops may also be **drilled in the field** in the same way as turnips, and afterwards thinned out with the hoe to the required distances apart. Thousand-headed kale can in this way be sown in March or April for use from October to March, and in August for late spring and summer feed. Drumheaded cabbage is often drilled in the spring for late autumn and early winter use.

White Mustard.—This is frequently grown as a catch-crop during summer, with the object of providing green food for feeding off towards autumn. Some 15 lb. of seed per acre are generally sown broadcast after a fine seed-bed has been prepared.

LEGUMINOUS FORAGE CROPS

Vetches or Tares.—These are sown principally with the object of providing keep for sheep, and green fodder for cattle and horses in spring, although they are sometimes taken as a crop for seed. They generally follow a white straw crop of some kind, and in light land districts they are often grown as a catch-crop between two main crops in the rotation. There are two varieties, 'the Winter' and 'the Spring,' the former of which is sown in the autumn and will stand the winter. By sowing at suitable intervals a succession of green food can be arranged on the farm for a large part of the year. The preparation of this crop is simple, a piece of corn stubble being ploughed after a dressing of farmyard manure has been applied and spread. The seed can then be broadcasted and merely harrowed in, or the land can be harrowed down first and the seed afterwards drilled at the rate of 2 to 3 bushels to the acre. When broadcasted rather more seed is generally used.

The crop, when ready, is generally folded off with sheep, the autumn-sown crops usually being fed off in May, and the spring-sown later in the summer, according to the date of sowing. When grown for seed the crop is cut and harvested in a similar manner to peas.

TRIFOLIUM OR CRIMSON CLOVER.—This is sown in the autumn as a catch-crop for spring and early summer keep. The cultivation is more simple than that required for any other crop, a corn stubble after harvest being merely well scratched with the drags, the seed then broadcasted on the surface, harrowed in, and finally rolled. No advantage is gained by a more thorough cultivation for this crop, as, although it requires a fine seed-bed on the surface, it likes the land quite firm and tight underneath. Ploughing, in fact, would have an injurious effect on this crop by rendering the soil much too loose, so that it would be impossible to get an even plant.

LUCERNE. — The cultivation of this plant has increased considerably during recent years. It is a valuable crop on many soils, especially dry calcareous loams, such as those overlying the chalk, where, owing to its deep roots striking into the interstices of the subjacent rock, it is able to obtain moisture, and throw up abundance of green food in a dry season. It does not do so well on soils where the subsoil is stiff and inclined to be wet.

Lucerne is sown either by itself or with a corn crop, with the object of remaining down a number of years. The best results, however, seem to be obtained where the crop is sown alone. Whichever way the crop is sown, the land chosen for the purpose should be in good condition, and a fine seed-bed should be prepared which is free from weeds. The seed is best drilled in rows at about a foot apart, so as to give an opportunity of cleaning the crop during its growth, for without hoeing the plant soon gives place to weeds. It is sometimes the practice to give an old lucerne ley a sharp harrowing in the winter with the heavy harrows, and this rough treatment seems in many cases to benefit the crop by

stirring the soil around the roots. Lucerne is generally cut green for soiling, and after it is established several cuttings may be taken during the summer. The number of years a lucerne ley will stand will depend upon the length of time it can be kept free from weeds, which will eventually grow up and smother it. It must then be broken up.

SAINFOIN.—This is a crop of great importance to the flockmaster, especially on limestone soils, such as are found on the chalk and oolitic formations. It is very similar in its habits and cultivation to lucerne, and also, owing to its deep roots, it is able to resist drought. It is generally sown about April with a corn crop following roots fed off with sheep. Importance should be paid to having the land quite clean before the seed is sown, otherwise there is a chance of the young sainfoin being choked by weeds.

The seed is commonly drilled in the husk in the 'rough' or 'unmilled' state, as it is called, at the rate of about a sack or 4 bushels to the acre. Sainfoin is usually cut for hay the year after the corn crop is cleared, and the method of securing the crop is the same as for clover hay. There are two varieties of sainfoin, the 'Common,' which is used for long leys, and the French or Giant variety, which is short-lived and only lasts two years.

Sainfoin leys are generally allowed to remain down from five to seven years, in some cases longer, the length of time being determined by the growth of weeds, which, as in the case of lucerne, finally get the mastery.

Land which has recently grown sainfoin seems, in some peculiar way, to become heartily sick of the crop, and it is impossible to grow it again successfully on the same soil till a number of years have elapsed.

Sainfoin is a most valuable crop to wean lambs upon, and in certain summers, when the lambs do not seem to make headway on any of the other forage crops of the farm, and they are troubled with scouring, a change to a sainfoin ley will often have a beneficial effect, and they will begin to pick up in condition and lay on flesh.

Both lucerne and sainfoin are crops more particularly suited to the warmer and more genial climate of the south of England.

Trefoil, Yellow Clover, Nonsuch, or Black Medick (*Medicago lupulina*).—This is a plant that will grow on almost any soil, but is specially suited to poor soils in dry climates. It is therefore commonly grown in mixtures of grasses and clovers on thin limestone soils, but on some of these soils, where it is indigenous it assumes the character of a weed.

Clovers and 'Seeds.'—Clovers, and mixtures of clovers and grasses intended to take a place in a rotation, are almost always sown in amongst cereal crops, very often at the same time that the corn is sown, but occasionally after the corn has made some progress in growth. On the other hand, they are but rarely sown on land which is not to carry a corn crop concurrently with them, for 'leys,' or '**seeds**,' as they are commonly termed, require to be on the land a full year before they are fit to feed. Although there is occasionally, during the first year, some little growth which may be fed, yet it is not sufficiently reliable for the crop to be sown with that object in view. The most common clovers grown in rotation are red or broad clover (*Trifolium pratense*), cow-grass (*T. pratense perenne*), white or Dutch clover (*T. repens*), alsike (*T. hybridum*), and trefoil (*Medicago lupulina*). All these are sown in one and the same manner.

Seeding.—When sown in wheat, barley, or oats, which have appeared above ground, 'seeds' may be **broadcasted** on the surface with a seed-barrow, and are then harrowed in very lightly with the lightest seed-harrows, or with a horse-rake. The horse-rake is preferable on loose land, as it can be set so that too much of the surface soil is not disturbed, thereby preventing an excess of earth being thrown upon the seed, which cannot successfully germinate if buried to a greater depth than about half an inch. The harrows are most useful when the land is firm, as is frequently the case where wheat is being grown. The seed may also be **drilled** with a light seed-drill, greater regularity of

germination being secured than by broadcasting. But, as the plants stand thickly in rows, they have not quite so good a chance of growing at subsequent periods, for they crowd one another. When drilled with a small-coulter drill, 'seeds' are best rolled in.

The seeding of clovers is often effected before the cereals are up, and they are then harrowed in during the final harrowing of the barley or oats. This is not always advisable, as sometimes the land 'caps,' or forms a hard surface on the top, which is injurious to both the corn and the clovers; and when the clover has germinated it is impossible, without destroying it, to stir the land. For this reason it is most usual, on wet land, to sow the clovers just as the barley is appearing through the soil. Where the land is much troubled with annual weeds it is wiser to postpone the sowing of the clovers until the corn has been hoed, and the usual custom in such cases is to sow the seed shortly before hoeing, so as to cover it in during the process of hoeing, harrowing being then unnecessary. When rye-grass or other grasses are sown as a mixture with clovers, the seeding is often effected in two operations, in order to avoid undue proportions of seed in different parts of the field. This is, indeed, necessary when the seeds are drilled with a brush-drill, or sown with a seed-barrow, but not when they are put in with a cup-drill.

When land is too frequently cropped with clover it becomes **clover-sick,** and is unable to carry the plant to maturity, as the crop dies off during autumn and winter, a minute eel-worm (*Tylenchus devastatrix*) attacking it in the root and stem, and destroying its life. A deficiency of lime and potash is conducive to clover-sickness; therefore, where there is reason to believe that these substances are lacking, they should be applied in the most convenient form in which they can be obtained in the locality. The surest method of preventing the disease is to refrain from growing red clover too frequently. This is best arranged by forming a sub-rotation of clovers in the general rotation. Thus, if red clover is taken in its proper position in the rota-

tion, but cow-grass or white clover is sown in its place four years after, and alsike grown four years later, then red clover again four years subsequently, red clover will only be on the land once in twelve years, and a plentiful supply of sheep-keep will be provided without risk of clover-sickness. In some localities a mixture of alsike and white clover is sown when red clover is omitted. [Clover-sickness is sometimes due to a fungus.]

After Management.—The after-management of the 'seeds' crop is very simple. If the land is loose it is necessary to compress it in the autumn, by means of rollers, or by the treading of sheep; but 'seeds' must not be fed too hard with sheep at that season. Sheep are the most perfect compressors of the soil, as they pinch the mould around the roots, whereas other forms of pressure are usually applied in broad sections, which cannot fit into the inequalities of the land. Sheep should not be put on heavy land in a wet autumn; but it is not often that clovers and 'seeds' require consolidating during such seasons. The 'seeds' should be rolled in the spring, and, if it is intended that the crop should be converted into hay, loose stones should be picked off the land, or they will prove troublesome at hay-time.

CULTIVATION OF POTATOES

Potatoes are a field crop of considerable importance in certain counties, such as Cheshire and Lincolnshire, parts of Yorkshire and Lancashire, and also in certain districts in Scotland and elsewhere. Although potatoes are often referred to as a 'root crop,' they are not roots at all from the botanical point of view, but the tubers are enlargements of underground stems, which are stored with reserve food materials, to be used in carrying on future growth (*see* p. 151). Fresh plants are obtained by a vegetative growth or development from the buds, or eyes, contained in the tubers, and thus the potato differs from other farm crops which reproduce themselves by a process of fertilization and the formation of seed. The potato, however, makes a fresh start

each year from the tuber, which is really a portion of the old plant that has died down the preceding year. For this reason a new variety of potato generally begins to lose its vigour after a few years' growth, as is shown by a falling off in the yield and the crop becoming more susceptible to attacks of the potato disease (*Phytophthora infestans*). Suitable changes of seed from time to time, as regards soil and climate, will help to prolong the life of a variety, but on an average this does not last more than from twelve to twenty years, and often less. Taking the above considerations into account, it is of importance to the grower to discover which varieties of potatoes are best suited to any particular soil and district, and thus to increase the productiveness of the crop. Potatoes may be divided into early, second-early or mid-season, and late, according to the time they are ready to harvest. One of the most profitable branches of potato culture is that of growing **early potatoes,** provided they can be got ready very early in the season before the great glut of new potatoes from abroad and elsewhere floods the markets of the United Kingdom. Certain conditions, however, are necessary to be successful in the cultivation of early potatoes. One of these is a suitable climate, free from late spring frosts; another is a deep, warm, well-drained friable soil, capable of being heavily manured. Methods must also be made use of to hasten the growth of the crop, such as putting the seed tubers into shallow trays or boxes, and allowing them to sprout previous to planting. In this way a growth is taking place in the box before the tuber is planted, and thus the grower can afford to wait a week or two longer for suitable weather before planting out in the field. A good deal of care and judgment must be used with regard to the regulation of light and temperature in the building in which the boxes are stored; the object being to obtain strong vigorous green shoots on the potatoes which will not easily break off. If the boxes are kept in the dark and at too high a temperature, long, weak, spindly shoots will be produced, which easily break off. Exposure to light and reduction of temperature will coun-

teract this tendency. Without the above necessary conditions the growing of early potatoes will be a very precarious business.

Potatoes flourish best on deep loose friable soils, such as the lighter loams, especially when they contain a fair amount of organic matter. Poor sandy soils, if heavily manured, will grow good crops, provided there is a sufficient rainfall, and even heavy clays, if suitably treated, may be made to grow them successfully.

Big crops are often obtained from recently broken up grass land, and the potatoes seem to revel in the mass of decaying vegetable matter derived from the old turf. Some of the choicest potatoes are raised on the old red sandstone and the marls and sands of the trias; those grown on the greensand are generally of good quality, and most of the light, mixed, gravelly loams produce high-class tubers. The rich fens and warp deposits yield immense crops, very good for change of seed, but the quality for eating purposes cannot be depended upon. Some heavy soils grow fair crops of potatoes, but as a rule these are not suited to strong clays with retentive subsoils, and it is often almost impossible to dig them on these soils in a wet autumn.

The question of cultivation is a matter of very great importance. Although the methods may vary somewhat in different districts and on different classes of soil, there are a few points which are essential everywhere. In the first place, the land must be thoroughly worked to a good depth, and it is necessary that the crop should be moulded up two or three times during its growth. Where grown as a field crop, potatoes, as a rule, take the place of roots and follow a grain crop of some sort, often oats. The land may be ploughed lightly in autumn and worked so as to remove any couch near the surface, but in any case it should receive a deep ploughing before the end of the year, so that the furrow may be exposed to the beneficial action of the winter's frost. It may be necessary in some cases to plough again in spring, but this will all depend upon circumstances and the state of cleanliness of the land. Farmyard manure may be applied in the autumn before the

winter ploughing, or may be spread in a short or rotten condition in the furrow in the spring. This latter method is generally followed on light sandy soils with porous subsoils, where there is a fear of a large proportion of the manure being lost by washing into the subsoil if applied too early.

Potatoes are grown on the ridge or on the flat, in the same manner as roots. When on the flat the rows are generally 20 to 30 inches apart, and a distance of 12 to 18 inches is allowed between the sets; on the ridge the distance from row to row is 24 to 30 inches and the sets 10 to 15 inches, according to variety.

The method of planting on the ridge is generally adopted in the damper climates of the north and west and on the heavier soils, whereas the flat system is more often followed on the drier soils of the south and east where the rainfall is less.

The **preparation of the seed-bed** is similar to that for roots. When growing on the ridge, the land, after it has been deeply worked and sufficient mould has been obtained, is set up in ridges, as soon as the ground is dry enough in spring, by means of the double-breasted or ridging plough. The manure carts then follow, and the dung, in a rotten state, is thrown out into small heaps, which are afterwards teased out by means of forks along the furrows. Any artificial manure used is then generally sown over the dung, and the sets are then placed in the furrow at the required distances apart. After this the double-breasted plough splits the ridges, thus covering up the seed sets and the manure, and enclosing them in the centres of the newly-formed ridges.

When grown on the flat the potatoes may either be ploughed in, the seed tubers being set in every third furrow and then covered with the ordinary plough, or the system of 'holing in' with the spade may be adopted, in which case the land is first reduced to a tilth. In this latter case the land is marked out in lines across the field, and a man with a spade makes holes at regular intervals along the rows, a boy who accompanies him dropping a potato into each hole as

it is opened. They then return, the man making holes on a line parallel to the first, and as he does this he fills in the previous holes so as to cover the potatoes; in this way the whole field is planted. Potatoes may also be planted by dibbling them in. The dibble is a thick stick pointed at one end, with which holes are made in the ground, the potatoes being dropped into the holes and afterwards covered with earth.

During its growth the crop must be kept clear of surface weeds by means of continual hand-hoeings and horse-hoeings, and it is often advisable, especially when growing on the ridge, to commence by running the light harrows over the surface, so as to break any crust which may have formed, and also to destroy annual weeds.

When the tops are some 8 to 10 inches high, it will be necessary to earth up the rows by means of the moulding plough, and this will also have to be done a second, and perhaps even a third, time during the summer.

The **selection of seed** is a matter of great importance for the success of the crop; and the newer varieties should as far as possible be chosen which have been shown to be suitable to the soil and climate of the district. These, as a rule, are bigger croppers, more vigorous in constitution, and give more profitable returns; and there is also less fear of loss from disease.

Change of seed from a different class of soil and climate at frequent intervals is advisable. Such a change usually results in healthier and heavier crops. The best results are to be expected from seed brought from a colder and more northerly climate; seed from a warmer climate will give an earlier crop, but the growth will not be so vigorous.

With regard to the best **size of seed** to use, medium sized sets which will pass through a $1\frac{3}{4}$ in. riddle, but not through a $1\frac{1}{2}$ in. will be more profitable to plant than either very large, or very small ones, although large sets will give a better yield.

It is usually the practice to cut large seed-tubers, at least two eyes or shoots being left on each set. The

results of recent experiments, however, tend to show that there is not much difference in the yield between planting whole and cut sets, when the same weight of seed is used per acre. It is a mistake to cut early and white-blossomed varieties, as these potatoes are more delicate and liable to decompose when cut.

The usual time of planting is from March to the beginning of May, according to the season. The early varieties should be planted first, the second-early next, and the main crop last.

From 12 to 15 cwt. of seed, according to the size, is the **amount** usually required to plant an acre, although in the potato-growing districts the quantity of seed used per acre is often greater than this. Potatoes are a surface-feeding crop, and require a liberal all-round manuring, containing the three essential ingredients—viz., nitrogen, phosphoric acid, and potash—to ensure an abundant yield.

Manuring.—Good crops may be grown with artificials alone, without dung, especially after 'seeds' or an old turf, but a dressing of farmyard manure is generally considered necessary for the early varieties.

Potatoes require plentiful supplies of potash for their starch development, and where a mixture of artificials is used it should contain a fair proportion of some potassic manure.

When large dressings of dung are employed artificial manures are not essential, but it is now considered more profitable to use a moderate dressing of dung—say, 12 to 15 tons to the acre—and supplement it with a complete mixture of artificials.

Such an artificial mixture might consist of—sulphate of ammonia, 1 cwt.; superphosphate, 3 cwt.; sulphate or muriate of potash, 1 cwt.; making, in all, 5 cwt. per acre.

Kainit is sometimes employed as a manure to supply potash, but recent tests seem to point to the wisdom of sowing it some time before planting, so that any impurities it contains may be washed into the subsoil, as these sometimes have a bad effect on young vegetation.

ESTIMATE AS TO COST OF GROWING CROPS IN A ROTATION

Having considered the cultivation of the various farm crops, it will be interesting to examine a few figures showing the cost of production and returns which may reasonably be expected from the growth of a series of crops in rotation. The 'four-course' being the typical rotation, on which most others are based, seems a fair one to take for this purpose. It is evidently unfair to strike a balance on one crop of the rotation only, such as 'roots,' because, this being the cleaning crop of the rotation, a large proportion of the expenditure on cultivations and manures must be spread over the rest of the course and a part debited to each crop. It will thus be necessary to summarize the expenditure and returns on the whole rotation, so as to be able to draw definite conclusions as to the true financial aspect of the case.

In the following estimates the costs of cultivation and produce obtained have been taken as representing a fair average of what might be expected on farms in the Midlands, where the soil is a medium loam, and capable of being ploughed by two horses.

In these calculations a horse is valued at 3*s.* per day and a man at 2*s.* 6*d.*; harvest wages are taken at 5*s.* per day.

FIRST YEAR (SWEDES).

Cost per acre.

	£	s.	d.
Ploughing in autumn (shallow)	0	8	6
Two draggings at 1s. 6d.	0	3	0
Rolling	0	1	0
Two harrowings at 9d.	0	1	6
Chain harrowing	0	0	8
Collecting and burning couch	0	3	0
Filling, carting and spreading dung, 12 loads at 10d.	0	10	0
Winter ploughing (deep)	0	12	0
Spring ploughing (cross)	0	8	0
Two cultivatings at 1s. 6d.	0	3	0

FIRST YEAR (SWEDES)—*Cost per acre—contd.*

	£	s.	d.
Dragging	0	1	3
Harrowing	0	0	9
Rolling	0	1	0
Drilling seed and superphosphate	0	2	0
Seed, 2 lb. at 9d.	0	1	6
Superphosphate, 3 cwt. at 3s.	0	9	0
Harrowing after drill...	0	0	9
Rolling after drill	0	0	9
Horse-hoeing	0	2	0
Hand-hoeing and singling	0	6	0
Horse-hoeing	0	2	0
Hand-hoeing (2nd time)	0	4	0
Horse-hoeing	0	2	0
Pulling, topping, cleaning and burying on field...	0	15	0
Rent, rates and taxes	1	5	0
	£6	3	8

Returns.

18 tons of swedes at 5s. per ton (consuming value) £4 10 0

SECOND YEAR (BARLEY).

Cost per acre.

	£	s.	d.
Ploughing	0	10	0
Two harrowings at 9d.	0	1	6
Rolling	0	1	0
Harrowing	0	0	9
Drilling	0	2	0
Seed, 3 bushels at 4s.	0	12	0
Harrowing	0	0	9
Rolling	0	1	0
Weeding	0	1	0
Harvesting	0	12	0
Threshing and marketing, 4½ qrs. at 2s. 4d. ...	0	10	6
Rent, rates and taxes	1	5	0
	£3	17	6

Returns.

	£	s.	d.
4½ qrs. of barley at 28s.	6	6	0
Straw at consuming value per acre	0	12	0
	£6	18	0

THIRD YEAR (SEEDS).

Cost per acre.

	£	s.	d.
Sowing 'seeds' with barrow	0	0	6
'Seeds' mixture	0	12	6
Light harrowing	0	0	6
Rolling	0	0	9
Haymaking	0	12	0
Rent, rates and taxes	1	5	0
	£2	11	3

Returns.

	£	s.	d.
30 cwt. 'seeds' hay at £2 per ton (consuming value)	3	0	0
Value of grazing	1	0	0
	£4	0	0

FOURTH YEAR (WHEAT).

Cost per acre.

	£	s.	d.
Ploughing	0	10	0
Rolling	0	1	0
Two harrowings at 9d.	0	1	6
Two draggings at 1s. 6d.	0	3	0
Harrowing	0	0	9
Drilling	0	2	0
Harrowing	0	0	9
Seed, 2½ bushels at 4s.	0	10	0
Pickling seed	0	0	3
Harrowing (spring)	0	0	9
Rolling	0	1	0
Weeding	0	1	0
Carting and sowing manure	0	0	6
1 cwt. nitrate of soda	0	10	0
Harvesting	0	12	0
Threshing and marketing, 4 qrs. at 2s. 6d. ...	0	10	0
Rent, rates and taxes	1	5	0
	£4	9	6

Returns.

	£	s.	d.
4 qrs. of wheat at 32s.	6	8	0
Straw at consuming value per acre	0	14	0
	£7	2	0

SUMMARY.

Costs.

	£	s.	d.
Roots (swedes)	6	3	8
Barley	3	17	6
Seeds	2	11	3
Wheat	4	9	6
	£17	1	11

Returns.

	£	s.	d.
Roots (consuming value)	4	10	0
Barley	6	18	0
Seeds (consuming value)	4	0	0
Wheat	7	2	0
	£22	10	0

This represents a profit of £5 8*s.* 1*d.* per acre on the whole rotation, or an average profit of say £1 7*s.* 0*d.* per acre per annum.

CHAPTER XVII.

HARDY FRUIT CULTURE

INTRODUCTION

The commercial fruit-growers of this country may be divided into two classes—first, the individuals who make fruit-growing their business, and, secondly, those who treat it as a subsidiary industry, though a none-the-less important one. Farmers may be included in the latter class, and the object in this chapter is not to deal exhaustively with the many phases of fruit culture, which would be impossible in the space at command, but to put in simple language those principles of fruit-growing which are most likely to be of practical use to the agricultural student, as well as to the farmer who cultivates

PLATE I.

1. Apple Tree in Bearing

PLATE I.—*continued.*

2. Bramley's Seedling Apple Trees in Orchard.

fruit partly for home consumption and also with a view to profit. It should be understood, however, that if fruit is to be a profitable part of farming, it must be treated seriously, and be given just that care and attention in cultivation which, in the ordinary way, is accorded to every other crop that is grown.

APPLES AND PEARS IN GRASS ORCHARDS

(PLATE I.)

In districts that are naturally adapted for fruit there is no part of a farm which offers greater possibilities for profit than a good orchard on grass, planted with standard trees of suitable varieties, but the gospel of orchard planting is not one to be preached in all circumstances, because attempts at forcing the hand of nature by planting orchards in places where soil and situation are unsuitable is only courting failure. The extent to which fruit is grown in the district, and the way trees flourish, are perhaps the best guides as to the adaptability of the locality, and it should be remembered that what is possible in a garden under the care of an expert is not so easy under the less controlled conditions of an orchard.

Soil and Situation.—For obvious reasons it is desirable that the orchard should be somewhere adjacent to the homestead, and a slope facing to the south or south-west is an excellent situation. It is a fatal error to plant fruit trees in waterlogged soil, and if these conditions prevail draining should be the initial operation. A deep and somewhat retentive loam is the best for apples, and though pears will succeed under these conditions, they prefer a rather lighter medium.

Trees and their Arrangement.—In planting a grass orchard the object is to get fruit from the trees above and grazing for stock beneath, therefore strong standard trees should be selected in the nursery, with stems so long that the heads are out of the reach of animals. The best way of arranging trees is alternately, or in the form of equilateral triangles, and strong growing

varieties, which are the best for orchards, should not be planted closer than 30 feet apart (fig. 174).

Planting (fig. 175, 1).—All things considered, the fall of the year is the best time for planting, November and December being the most suitable months. Having marked out the site of each tree, the turf should be removed in a circle not less than 5 feet in diameter, and the top foot of soil be taken out. The next step is to break up the lower

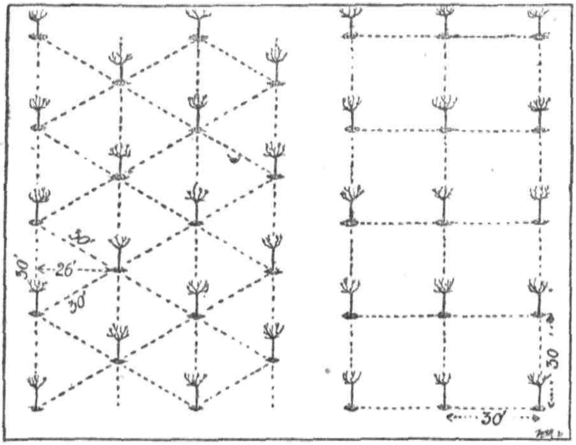


FIG. 174.—ARRANGEMENT OF ORCHARD, showing trees planted in equilateral triangles, and in squares.

soil in the hole with spade or fork, and then cut up the turf and spread it on the top of the lower soil. A little of the best soil should then be scattered over the broken turf, and the whole be trodden down evenly. Everything is now ready for the stake, which may be of sawn deal 8 feet long and 2½ inches thick, and creosoted for purposes of preservation. After the stake has been driven firmly into the ground, the tree should be placed in position with roots spread out, and three or four inches of soil be spread over the latter

and trodden down. As some sinking will take place, the soil should be left round the tree in the form of a slight mound, and on on account should the grass be allowed

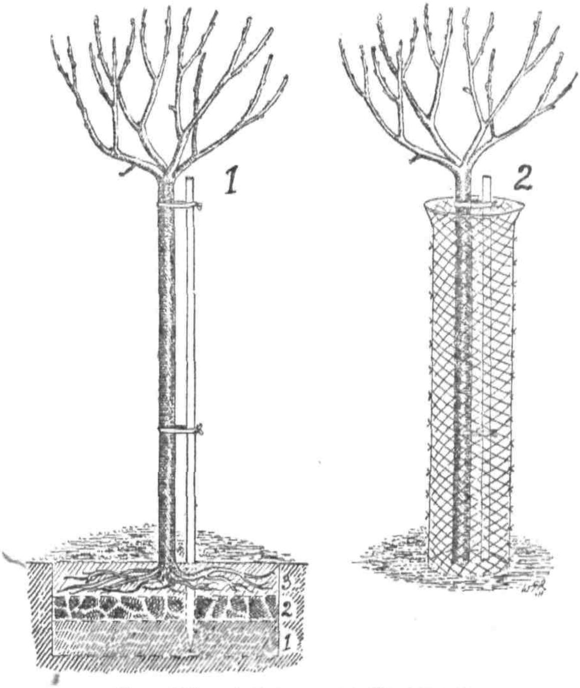


FIG. 175.—A LESSON IN PLANTING.

(1) 1, Subsoil broken up at the bottom of the hole. 2, Turf taken from surface, cut up, and placed underneath the roots. 3, Roots spread out in the soil.

(2) Standard tree planted, staked, and protected with wire guard.

to grow to within 2 feet 6 inches of the stem for several years. This is very important, as the growth of turf over the roots of newly-planted trees has a detrimental

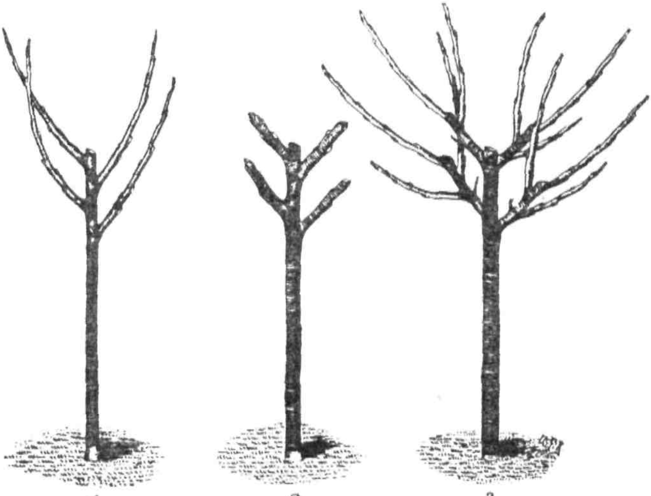
effect on the development of the latter, and weeds should be kept down by periodically hoeing.

Tying and Protecting (fig. 175, 2).—It is essential that the tree should be fastened securely to the stake to avoid damage by chafing or rubbing, and a simple contrivance is to wrap a strip of old sacking round the stem and fasten it to the stake with tarred cord. If animals have access to the orchard some form of protection is essential, and nothing is better than circular guards of stout wire netting, further strengthened by strands of strong barbed wire. These guards reach to the top of the stake, they can be easily removed if necessary, and they afford protection against ground game as well as stock.

The First Pruning (fig. 176).—The prime object in pruning a newly-planted tree is to promote growth, and a much-debated point is whether the pruning should be done in the spring following the planting, or whether it is better to let the tree stand a whole year before it is operated on. The balance of evidence points to the conclusion that the best results are generally obtained with orchard standards when the first pruning is effected *not* in the spring following the planting, but a year later. The process is as follows: Cut out weakly side shoots that are useless for making branches, leaving only the **leaders**, or main growths, and these, in turn, should be cut back to about one third their original length, always taking care to cut just *above* a bud on the outside of the branch.

After-Pruning.—The process just described has for its object the multiplication of branches to form the head of the tree, and if there is a sparsity of strong shoots the leaders may be shortened again the second year to encourage more growth, but when the head of a standard tree is formed there should be no more shortening back, and the pruning year by year should consist in removing superfluous branches that rub and cross each other, tending to crowd up the centre of the tree. **If the trees are systematically treated in this way they never get into that hopelessly overcrowded condition which is the fault of so many trees in old orchards.**

Pruning Old Orchard Trees.—In dealing with an old tree that has been neglected in the matter of pruning considerable judgment is required, or more harm than good may be done, and the first thing is to remove all dead wood. The next operation is to carefully thin the inner branches where they are too crowded, the



1. 2. 3.

FIG. 176.—FIRST PRUNING OF A STANDARD TREE.

1, The young standard. 2, Young shoots cut back to about one-third their original length, each cut made just above an outside bud. 3, Result of the pruning: branches increased and foundation of tree laid.

object being to let air and light into the tree. No hard and fast rules can be laid down in dealing with a full-grown tree, but over-pruning should be avoided. Thick limbs should be cut with a saw quite close to the main stem, and if the rough surface left by the saw is smoothed over with a knife or chisel and painted with Stockholm tar, the young bark will quickly grow over the cut

surface and make a perfect heal. On the other hand, if rough snags are left, the latter decay, wet gets in, and hollows are finally formed in the main limbs of the tree.

Manuring Orchards.—Generally speaking, it is not necessary to add manure to the soil when planting young trees, but if a mulching of decayed manure is afterwards placed over the roots it helps to conserve moisture and encourages surface root action. In addition to the benefit obtained from manure dropped by grazing animals, however, trees in full bearing should have periodical dressings of dung spread over the roots, and it is a good thing to empty the contents of liquid manure tanks under the trees in the winter when the ground is damp. Concentrated manures supplying phosphates and potash are good for orchard trees, and a suitable mixture for application in the winter may consist of 4 cwt. of basic slag and 3 cwt. of kainit to the acre.

Varieties.—When planting an orchard with a view to marketing the fruit, it is a great mistake to include too many varieties, because the result of this is that no bulk of any one kind of fruit is grown. The selection of varieties must to some extent be governed by local circumstances, but care should be taken to plant trees which, in addition to good bearing qualities, are possessed of vigorous constitutions. A short list of apples and pears suitable for orchard planting is given below.

A dozen good cooking apples:—

Early.	Succession.	Late.
Lord Grosvenor.	Bismarck.	Annie Elizabeth.
Ecklinville.	Warner's King.	Bramley's Seedling.
Grenadier.	Lord Derby.	Beauty of Kent.
Pott's Seedling.	Gascoyne's Seedling.	Newton Wonder.

A dozen good dessert apples:—

Early.	Succession.	Late.
Devonshire Quarrenden.	Allington Pippin.	Hormead Pearmain.
Beauty of Bath.	Cox's Orange Pippin.	Christmas Pearmain.
Mr. Gladstone.	King of the Pippins.	Blenheim Orange.
Yellow Ingestrie.	Fearn's Pippin.	Court Pendû Plat.

Six good pears:—

Doyenné d'Été.	Pitmaston Duchess.	Marie Louise d'Uccle.
Williams' Bon Chrêtien.	Louise Bonne of Jersey.	
Hessle.		

STONE FRUITS IN ORCHARDS

CHERRIES.—The cherry orchards in Kent and elsewhere afford evidence of the usefulness of this fruit in districts where natural conditions are suitable, but the trees should always be planted in sufficient quantity to merit the necessary expenditure in protecting the fruit from birds.

Planting and Pruning.—Thirty feet apart, as advised for apples in orchards, is a good distance to allow between the trees, and the same method of planting may be applied. Cherries have a marked dislike to the knife, and after cutting back newly-planted trees, to encourage the formation of a good head, little pruning, other than the removal of any dead branches, is required. Cherries flourish in a soil of a calcareous nature, and the grass in orchards should be kept down by close grazing. The following is a selection of six good varieties:—

May Duke.	Elton Heart.	Bigarreau Napoleon.
Kentish Bigarreau.	Black Heart.	Black Tartarian.

PLUMS.—As a rule, plums are grown more in cultivated plantations than grass orchards, but in what are known as plum districts they succeed well under the latter conditions. Plums in orchards are better grown rather close together, 18 feet apart being a fair distance. They should be planted in the same way as apples, and when established very little pruning is required. (For a selection of varieties, *see* p. 373.)

DAMSONS.—The damson is a fruit which seems to adapt itself to certain localities, and under suitable conditions there is no fruit more useful. Damsons may be grown on the outskirts of plantations to provide shelter, also in grass orchards; and in some parts trees planted

in hedgerows produce good crops of fruit. The damson is another fruit which does not trouble the pruner much after the tree is established. The known varieties are mostly of local origin, and the Cheshire prune is one of the best. The Crittenden is a close-growing variety that bears well, and Bradley's King is also worth cultivating.

MIXED FRUIT PLANTATIONS

(PLATE II.)

The system of growing fruit in mixed plantations under continual cultivation has increased considerably in recent years, and is the favoured method of the commercial grower, whose object is to get the best return from the land in the shortest time.

Position and Preparations for Planting.—Provided there is sufficient depth and the quality is of good average character, most soils suitable for arable crops will grow fruit, but the situation should be fairly elevated if possible, to escape spring frosts, and shelter from prevailing winds should be provided if necessary. The preparation of the land must be thorough in every respect, draining being the first operation, if this is necessary, followed by deep ploughings, and subsoiling or bastard trenching with the spade to ensure deep cultivation and the eradication of weeds. No greater mistake could be made than that of planting fruit on foul land. The question of manure must be decided by the condition of the land, but, if it is needed, a liberal dressing of stable manure should form part of the preparation.

The Arrangement of Trees and Bushes.—There are different ways of setting out fruit plantations with the object of utilizing the land to the best advantage, and small fruits are included to give a return until the other trees are in full bearing, and demand the space occupied by the former. The types of trees employed are half-standard apples, plums, or pears, bush apples and pears, with gooseberries, currants, raspberries, and strawberries, in the way of bottom fruit, though it is some-

times more convenient not to include the last two fruits, but grow them in fields to themselves. A typical method of arranging a plantation is to plant half-standard trees 24 feet apart, with a bush tree equidistant between the standards in the row, and a row of bush trees 12 feet

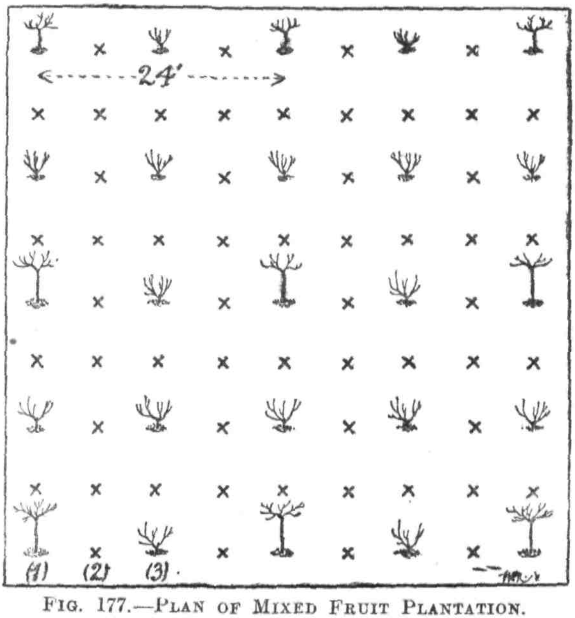


FIG. 177.—PLAN OF MIXED FRUIT PLANTATION.

(1) Half-standard trees 24 ft. apart; bush apples or pears midway between them; x, gooseberries or currants.
(2) Gooseberries or currants 6 ft. apart. Strawberries or raspberries can be substituted.
(3) Bush apples or pears 12 ft. apart, with gooseberries between.

apart between the rows of standards (fig. 177). This will also allow for the temporary planting of rows of strawberries, if desirable, and there is room for bottom fruit bushes—*i.e.*, gooseberries and currants—to be planted at equal distances between the trees.

Planting and Cultivating.—Favourable weather in the autumn or winter should be chosen for planting, and though on land that has been recently cultivated the process of planting need not be so elaborate as that recommended for orchard trees, holes large enough to accommodate the roots should be prepared and deep planting should be avoided. All bruised parts should be trimmed off the roots, and the soil be pressed firmly round the latter. In the cultivation of plantations both horse and hand labour are employed with the desirable objects of checking weeds and keeping the surface soil in a crumbling condition.

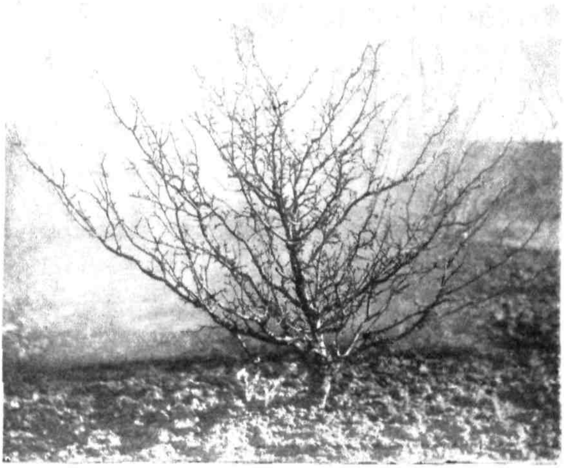
Pruning Half-standards.—The methods adopted for orchard trees are applicable to half-standards in plantations, the object being to allow free growth after the heads of the trees are formed (Plate II,).

Bush and Pyramid Trees (Plate II.).—Young trees from the nursery may be shortened back, as advised for standards, either the spring following the planting or a year later, and for several years it may be necessary to shorten the leading shoots about half-way, and reduce the side shoots in order to get well-balanced and shapely trees (figs. 178 and 179). It should be remembered, however, that the natural sequence of severe pruning is growth, and when the trees are well established the use of the knife may be well confined to the removal of overcrowded branches.

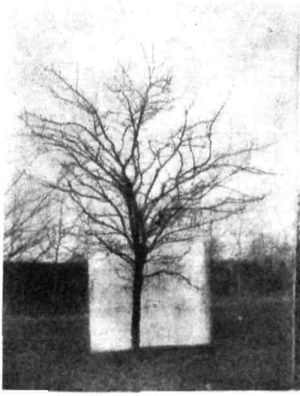
Gooseberries.—Young newly-planted gooseberries should have their leading shoots shortened back to encourage more growth (fig. 184), but severe pruning should be avoided with established bushes, and judgment should be exercised in the pruning, which consists of thinning out the wood sufficiently to admit air and sunlight, and facilitate picking operations. Strong shoots of the previous season's growth may be shortened back a little, but as much young wood should be left as is consistent with the above principles.

Red Currants.—Red currants fruit on spurs on the old wood, but at the base of the young side shoots, and the most profitable red currant bush is one that is furnished with seven or eight main branches that

PLATE II.



BUSH APPLE.



HALF-STANDARD PLUM.

PYRAMID PEAR.

produce fruit all the way down, with adequate space between them. After young bushes are planted the

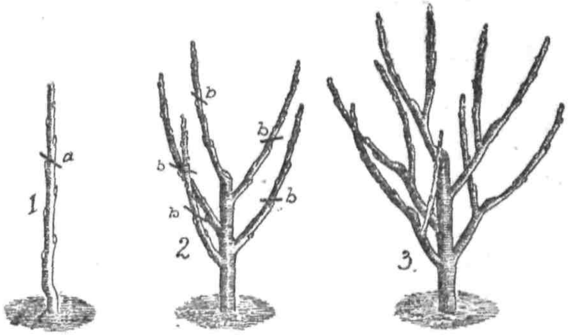


FIG. 178.—FORMING A BUSH APPLE.

(1) Maiden tree, cut back to *a*.
(2) Two-year old tree, showing the result of cutting; the shoots are now cut back to *b* to create growth.
(3) Result of the second pruning: three-year old tree with well-formed head.

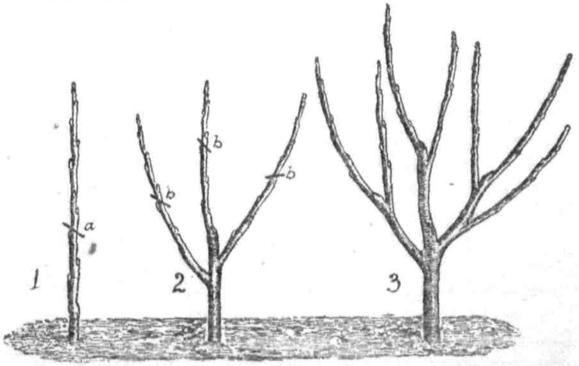


FIG. 179.—FORMING A PYRAMID TREE.

(1) Maiden tree; *a*, point to which it is cut back.
(2) Two-year old pyramid, showing result of cutting; *b*, point to which shoots are cut.
(3) Three-year old pyramid, with perpendicular stem through **centre.**

shoots should be shortened back (fig. 185), in order to get more branches, and when a sufficient complement is obtained the annual pruning consists of shortening back the side shoots on the main branches to within two buds of the base. The leading shoots must also be shortened, but a few inches should be left each year for extension.

Black Currants.—These bushes produce most of their fruit on wood of the previous season's growth, and newly planted bushes should be cut hard the first year or two to encourage strong growth (fig. 186). The subsequent pruning consists of avoiding overcrowding by thinning out old branches that have little young wood on them, but as much young wood should be left as possible.

Raspberries.—Newly-planted raspberry canes, which can be put out a foot apart in rows, or in clumps 6 feet apart, three canes in a clump, should be cut back to within a foot of the ground, and the reasonable result of this is that the canes produce strong growths for the next year, which can hardly be expected if the cane is hampered by fruit-bearing the first season. When an established raspberry cane has borne its crop of fruit, however, it has done its work, and may be cut out at the end of the summer to make room for its successor, which may be left its full length till the following spring, when the unripened tip can be cut off.

Logan Berries.—This useful fruit has become deservedly popular in recent years, and is suitable for training on trellises and fences, and other places where its long bramble-like growths can ramble. The plant is very blackberry-like in habit, and pruning consists of thinning out the old growths each year, to make room for the young canes. Owing to its vigorous habit, rich soil is not desirable for logan berries.

Manuring.—It is obvious that there is a big strain on the resources of the land in a fruit plantation, and deficiencies of plant-food must be made good by dressings of stable manure and applications of artificials. Phosphates and potash are the chief requirements of fruit trees, and these may be supplied by top dressings of 5 cwt. of superphosphate, or basic slag, according to

the nature of the soil, and 2 cwt. of sulphate of potash, to the acre. If trees are making good growth, applications of nitrogen are unnecessary, but weakly specimens are helped by light surface dressings of nitrate of soda in the spring.

PROFITABLE VARIETIES FOR PLANTATION CULTURE

12 cooking apples:—

Early.	Succession.	Late.
Early Victoria.	Cellini Pippin.	Lane's Prince Albert.
Lord Grosvenor.	Warner's King.	Bramley's Seedling
Stirling Castle.	Bismarck.	Annie Elizabeth.
Ecklinville.	Gascoyne's Seedling.	Newton Wonder.

9 dessert apples:—

Worcester Pearmain.	Cox's Orange Pippin.	Christmas Pearmain
Beauty of Bath.	King of the Pippins.	Scarlet Nonpareil.
Duchess of Oldenburg.	Allington Pippin.	Hormead Pearmain.

9 good pears:—

William's Bon Chrêtien.	Doyenné du Comice	Pitmaston Duchess.
Doyenné d'Eté.	Louise Bonne of Jersey.	Glou Morceau
Clapp's Favourite.	Émile d'Heyst.	Winter Nelis.

6 good plums:—

Early Prolific.	Pershore.	Pond's Seedling.
Victoria.	Czar.	Belle de Louvain.

6 good gooseberries:—

May Duke.	Crown Bob.	Lancashire Lad.
Keepsake.	Whinham's Industry.	Leveller.

Red currants:—

Raby Castle. New Red Dutch.

Black currants:—

Boskoop Giant. Baldwin's. Lee's Prolific.

Raspberries:—

Superlative. Norwich Wonder. Hornet.

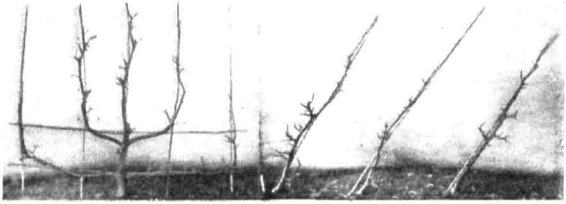
STRAWBERRIES FOR MARKET

The commercial culture of strawberries is mostly confined to certain areas where natural conditions are suitable and pickers are available, the latter point being an important one if a large quantity of fruit is grown. Under favourable circumstances strawberries are not a difficult crop to grow, but the land should be clean and in good heart. Rooted runners are planted in the autumn or early spring, about 18 inches apart, with 2½ feet between the rows, which allows for cultivation, and about 12,000 plants are required to the acre. The plants last three or four years, as a rule, and cultural operations during the period consist of hoeing and manuring, littering with straw before the fruit ripens, and trimming off runners and old leaves after the crop is picked. Market growers do not favour many varieties, and those most widely grown are Royal Sovereign, Sir Joseph Paxton, Monarch, and British Queen in favoured districts.

GENERAL CONSIDERATIONS

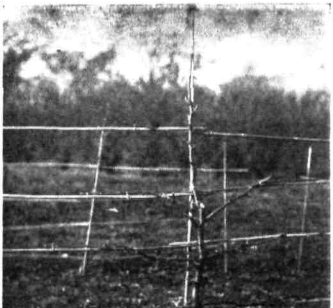
Picking, packing, grading, marketing, and storage of fruit are all items of importance to the market grower, and each in its turn must receive due attention in order that the produce may be disposed of to the best advantage. In short, commercial fruit growing demands the exercise of practical knowledge and judgment, as well as business ability, and the idea which seems to prevail in some quarters that it is a short cut to wealth is an erroneous one. It has its possibilities, and its prospects for the future are, on the whole, favourable, but in

PLATE III.



PALMETTE VERRIER TRAINED APPLE.

SINGLE CORDON APPLES.



HORIZONTAL TRAINED APPLE.

taking up fruit-growing as a business venture due allowance should always be made for those circumstances which are uncontrolled by the grower.

FRUIT IN THE GARDEN

(PLATE III.)

Most of the instructions already given are applicable to fruit in the garden, and the following hints have bearing on points not already considered.

Utilizing Wall Space.—Nothing is more pleasing or profitable in its way than a well-trained wall-tree, and yet the waste of wall space in the country is deplorable. Fan-trained trees, espaliers, and cordons can be obtained from a nursery for a few shillings each, and while the warmest positions may be accorded to peaches, nectarines, apricots, pears and dessert plums, a wall facing the north is a suitable position for Morello cherries. The planting of wall-trees entails some responsibility, for unless the work begun by the nurseryman is carried on, and due attention is paid to pruning and training, the tree quickly grows wild, and is an eyesore rather than an ornament.

Espaliers and Cordons (PLATE III.).—Espalier apples and pears are well adapted for planting alongside garden walks where it is desirable to utilize space, and **cordons,** or single-stemmed trees, are useful for furnishing comparatively low walls or filling spaces where there is not room for spreading trees. Most of the best varieties of pears succeed admirably as cordons, which is one of the best methods of growing this fruit.

Strawberries in the Garden.—The quickest method of establishing a strawberry bed is to place small pots filled with soil round fruiting plants in the summer and peg the runners from the latter into the pots. These runners soon establish themselves in the pots, and if planted out in August or September they get established the same season, and bear a good crop of fruit the next.

Root Pruning.—The pruning of roots is not infrequently a necessity in garden fruit culture, and the

need of it is generally brought about by over-luxuriance in the growth of young trees, and the severe branch pruning to which older specimens are subjected, because the natural sequence of severe pruning is growth. The object of root pruning is to check the excessive vigour of growth and encourage fruit bearing, and the best way to treat an over-luxuriant young tree is to take it up in the autumn, shorten back the tap roots and replant it. In the case of an older tree a trench should be taken out some distance from the stem in the autumn, and by working underneath in the direction of the tree the tap root will be found. This should be cleanly cut, and in filling up the trench the uninjured fibrous roots should be laid out close to the surface and covered with soil.

Summer Pruning.—Espaliers, cordons, bushes, and pyramids in the garden may be summer pruned with advantage, with the object of removing superfluous growth and diverting the sap towards the development of the fruit and the formation of fruit buds. Briefly expressed, summer pruning consists in shortening back lateral shoots to about five leaves from the base early in August, and this may be done by breaking the shoots over the blade of a knife. The shoots should not be shortened closer than five leaves, or the object of the operation may be defeated by the basal buds breaking into growth instead of remaining dormant; and the leading shoots should be left intact. The necessary shortening of the latter can be done at the winter pruning, and the shortened side shoots be cut a little further in.

PROPAGATION OF FRUIT

Stocks.—Apples, pears, and the various stone fruits are propagated by budding or grafting them on some kind of stock, which has a certain influence on the growth and habit of the tree. For instance, if an **apple tree** is worked on the wild crab stock, it is encouraged to grow a stout stem and is suitable for an orchard standard, but if worked on the broad-leaved Paradise

stock the fibrous root action of the latter prevails, the tree comes into bearing more quickly, does not grow so vigorously, and is more adapted for a bush. It may be taken, then, that, with certain exceptions, the Paradise is the best stock for bush apples, and the more vigorous crab stock for standards. Standard **pears** are mostly worked on the common pear, and pyramids on the quince stock. Dwarf **cherries** are generally budded on the Mahaleb stock, and standards on wild cherry (gean) seedlings, while **peaches, nectarines,** and **plums** are worked on different types of plum stocks. **Damsons** and some local varieties of plums are grown on their own roots.

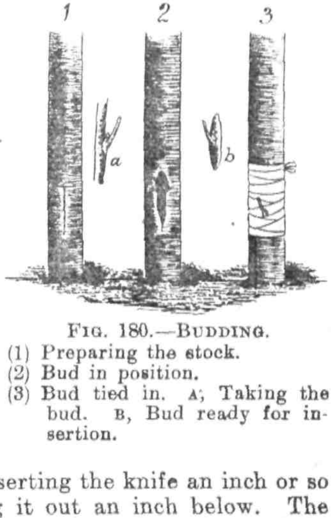


FIG. 180.—BUDDING.
(1) Preparing the stock.
(2) Bud in position.
(3) Bud tied in. A, Taking the bud. B, Bud ready for insertion.

BUDDING (fig. 180).—This is the favourite method of propagation with nurserymen, and stocks are budded close to the ground in July and August. To prepare the stock for the bud the operator cuts a T-shaped incision in the bark, which is raised slightly on either side to let in the bud. The bud is taken from a shoot of the current season's growth by inserting the knife an inch or so above a leaf and bringing it out an inch below. The leaf is cut off, but a portion of the stalk is left to hold the bud by, and the thin layer of pith underneath is removed with the thumb and finger, but this must be done carefully so as not to injure or drag out the interior of the bud, which is the growing germ. The prepared bud must not be allowed to get dry before it is slipped into the incision in the bark, and this done it should be wrapped round with worsted. The swelling of the bud is an indication that it has taken, and when

growth commences in the spring, the head of the stock should be cut off to within four inches of the union, this part being left to tie the growth to the first season lest it should be blown off. Fig. 181 represents a budded pear, in which the stock is used as a stake to support the young plant.

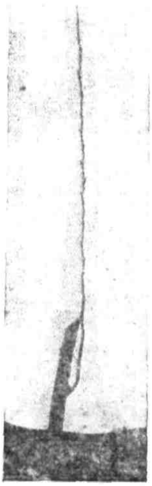


FIG. 181.—BUDDED PEAR.

GRAFTING.—This operation serves two purposes; it may be employed in propagation as a substitute for budding, though it is not so good, and also for the purpose of changing the character of established trees, which is the more valuable purpose served.

Taking the Graft.—The graft or scion is a piece of young growth, about four inches long, and furnished with wood buds. April is the best month for grafting, but it is an advantage to cut the scions a month or two beforehand, and lay them in the ground in a shady part of the garden.

Whip or Tongue Grafting (fig. 182).—This method may be employed in all cases where the stock and scion are about the same thickness, and it is highly important that the inner layers of the bark of the two be brought into direct contact with each other. To prepare the stock, make an upward sloping cut about two inches long, and midway in this make a downward cut in the slanting face. The scion is prepared in a corresponding manner, the tongue fits into the incision in the stock, and the two are bound together ready for the wax or clay.

Grafting large Trees.—In cutting back a big tree for grafting the limbs should not be severed too close to the main stem, but at about the second pair of forks, and the tops of the branches should be made smooth with a knife after being cut through with a saw. When grafting an apple that is past the vigour of youth a strong growing variety should be selected, and there is none better for the purpose than Bramley's seedling.

Crown Grafting (fig. 183).—The advantages of this method, suitable for big trees, is that there is no splitting of the limbs. Two to four grafts may be put on each branch, according to the thickness of the latter, and in preparation for the scion a sharp downward slit is made in the bark about three inches long. The scion

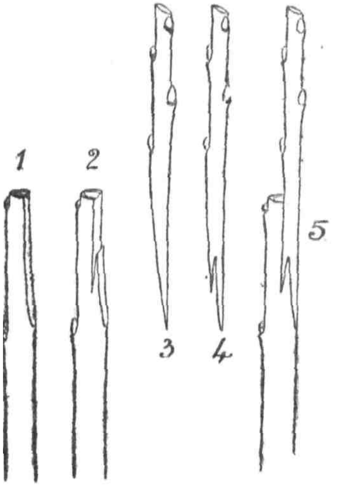


Fig. 182.—Whip Grafting.

(1) Stock showing upward cut.
(2) Stock ready for the scion.
(3) Scion pared down.
(4) Scion showing tongue.
(5) Scion fitted on to the stock.

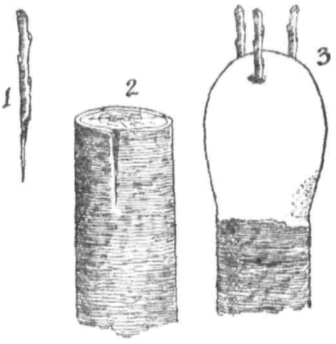


Fig. 183.—Crown Grafting.

(1) Scion prepared.
(2) Stock with bark slit and opened to receive scions.
(3) Scions fixed, tied, and covered with wax or clay to exclude air.

is prepared as in the case of the whip graft, but without the tongue cut, and, after raising the bark on either side of the slit in the stock, the graft is slipped into its position and tied round.

Cleft Grafting.—There are some objections to this method, as the stock must necessarily be split or sawn, and there is danger of the wet getting in and causing decay; but, on the other hand, it has its advantages, particularly in windy situations, as the grafts are not so liable to blow out.

Either two or four grafts may be put on a limb, according to the thickness of the latter, and in preparation the branch is split across to a depth of about two inches by means of a mallet and chisel. After making the cleft, a small wedge of wood should be inserted to keep it open, and after paring down the bark on either side of the cleft to get a smooth surface, the grafts should be pared down in the shape of a triangular wedge and slipped into the cleft, taking care that the inner barks of stock and scion are brought into immediate contact with each other. When the wedge is withdrawn the wood will come together, and hold the grafts securely in position.

Grafting Clay.—In all the above methods of grafting it is very essential to exclude air from the points of union, and to effect this purpose some persons prefer the primitive clay ball, which is made by kneading damp pliable clay and cow-dung together into a paste, and mixing with it some short hay. If the hands are wetted and the clay is plastered round the graft in the form of a cone, it will stick as long as it is required.

Grafting Wax.—This is advised in preference to clay, as it is equally effective and more easily applied. The following is a good recipe for a grafting wax, to be used warm:—

1 pint olive oil.	1 lb. yellow wax.
1 lb. Burgundy pitch.	2 oz. resin.

The ingredients should be put together in an old saucepan, melted down slowly, and applied with a brush, in a warm state, but not so hot as to injure the tissue of the bark with which it is brought into contact.

Cuttings.—**Gooseberries** are readily propagated from cuttings taken in the autumn as soon as the leaves have fallen (fig. 184). Young well-ripened shoots, 12 to 15 inches long, should be selected for the purpose, and they should be severed just below a bud. The end of the shoot should be cut back a little, and all the buds down the stem removed except four or five at the top. The shoots from these

are intended to form the first branches of the young bush, and the remainder are removed in order to get the bush with a clean stem above the ground. Cuttings may be inserted four inches deep and about the same distance apart. It is important to make them firm in the ground by treading. The cuttings strike root in the spring, and vigorous young bushes may be transplanted the following autumn. The remainder should have their shoots shortened back, and be left another year before they are removed from the nursery.

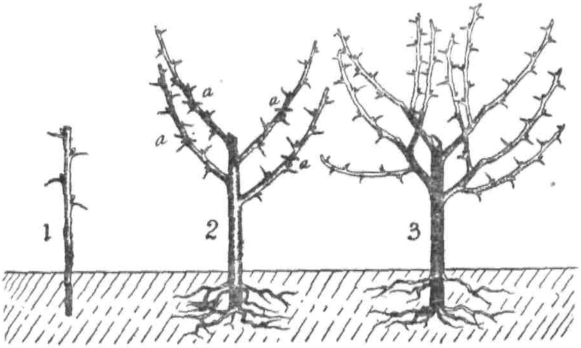


FIG. 184.—PROPAGATING GOOSEBERRIES.
(1) Cutting with lower buds removed, and inserted 4 ins. deep.
(2) Year old plant; *a*, Point to which shoots are cut back.
(3) Two-year old bush, showing the result of pruning.

Red and White Currants (fig. 185).—Cuttings of these fruits are prepared in the same way as gooseberries, but owing to the upright nature of the growth it is not necessary to have such long stems above the ground, and short sturdy shoots, about nine inches long, are suitable for the purpose.

Black Currants (fig. 186).—Young shoots, eight or nine inches long, are suitable for cuttings, and the tips should be removed, but not the lower buds, as it is desirable in black currants to encourage young growths to spring

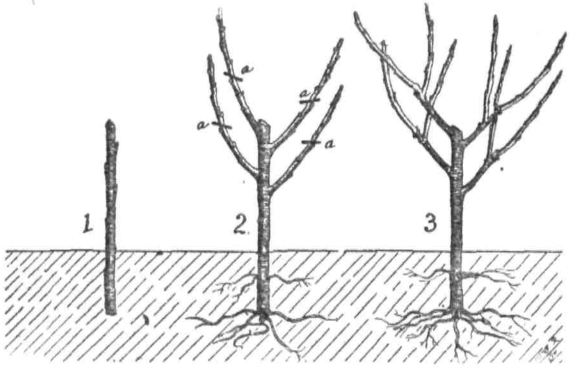


FIG. 185.—PROPAGATING RED AND WHITE CURRANTS.
(1) Cutting with lower buds removed and inserted 4 ins. deep.
(2) Year old plant; *a*, Point to which shoots are cut back.
(3) Two-year old bush, showing results of pruning.

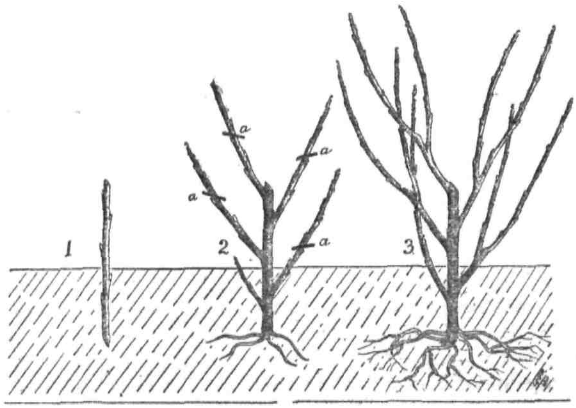


FIG. 186.—PROPAGATING BLACK CURRANT.
(1) Black currant cutting with none of the lower buds removed.
(2) Year old plant; *a*, Point to which shoots are cut back.
(3) Two-year old bush, furnished with young wood.

up from the base. To facilitate this, the young shoots on year-old bushes should be cut back to two buds, as this will encourage them to send up strong growths the season following.

SUCKERS.—**Raspberries**: No fruit is more easily propagated by suckers than the raspberry, and the operation consists of taking up young and medium-sized canes in the autumn with fibrous roots attached, and planting them where they are intended to grow.

Logan Berries.—These are readily propagated by divisions of the root in the winter, or if young growths are pegged down in the ground they quickly take root, and may then be detached from the parent and transplanted.

RUNNERS.—**Strawberries**: If strawberries are intended to fruit the first year the runners must be rooted in pots, as already described (p. 375), but runners that have rooted in the soil will fruit the first year if taken up and transplanted in the autumn or spring.

CHAPTER XVIII.

FUNGUS PESTS

FUNGI belongs to the THALLOPHYTA, the lowest division of the vegetable kingdom, in which the plant-body is not subdivided into root, stem, and leaf. One of the most familiar forms is the **mushroom** (*Agaricus campestris*), which grows naturally upon decaying organic matter in pastures. Examine one, and note the **stipes** or stalk, the **pileus** or cap, and, on the **under** surface of the latter, the **lamellæ** or **gills**, from which arise the **spores** that produce fresh mushrooms. It is, in fact, a reproductive structure, and arises from a delicate fibrous mass, the 'spawn,' that lives underground. Both this and the mushrooms it produces are made up

of delicate branching threads or **hyphæ**, closely compacted together, and collectively known as a **mycelium.**

Yeast (*Saccharomyces Cerevisiæ*), or barm, consists of innumerable minute yeast plants (fig. 187), which are likewise fungi. They consume oxygen and set free carbon dioxide, the conversion of solutions of sugar into alcohol, as in the brewer's vat, being an accompaniment of the process.

Another familiar type of fungus is afforded by the bluish or greenish-white **moulds**, such as grow upon damp boots, or upon jam, or upon horse-dung in warm weather, or in the substance of a ripening cheese. Examined with even an ordinary magnifying glass, the surface of such a mould can often be seen to be covered with a fine dust, which may be rubbed off with the finger. This dust is made up of exceedingly minute **spores**, which can only be studied by means of the microscope.

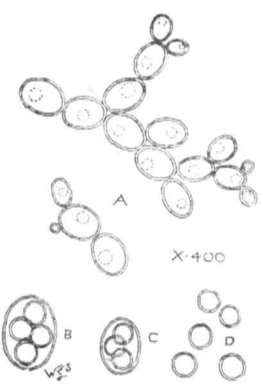


FIG. 187.—THE YEAST FUNGUS, *Saccharomyces Cerevisiæ*.

A, two bud colonies of yeast.

B, C, ascospores (*see* p. 394) containing daughter cells

D, free spores.

Under suitable conditions of warmth and moisture, the fungus spore, which is filled with living substance or protoplasm, will germinate. In the act of germination there grows from the spore a delicate thread-like hypha, and, when a number of spores germinate beside each other, the hyphæ, by interlacing, form a felt-like mycelium. This last-named structure may, however, be the product of a single spore.

The germination of a fungus spore, it will be noticed, is a much simpler process than that of a seed. Every seed contains a dormant embryo, which is a sexual product, and when the seed germinates, it is the embryo

that grows. The germination of a spore, on the other hand, is very similar to that of a pollen grain (p. 164), which is, in fact, a kind of spore. It is useful, therefore, to observe a clear distinction between the **spore** of a fungus and the **seed** of a flowering plant.

Short upright branches grow outward or upward from the mycelium of the mould, and, at the free ends of these, fresh spores are produced, all of which are capable of growing, and thereby of spreading the fungus.

Fungi differ from ordinary green plants in that they **contain no chlorophyll.** They are, therefore, unable (p. 143) to build up starch from the elements that enter into the composition of carbon dioxide and water. As a consequence they have to obtain food by stealing it from other plants, and even from animals, and hence many of them lead a life of parasitism. An oft-seen example is afforded in the **canker of the apple tree,** produced by a fungus, *Nectria ditissima*, the spores of which lodge upon any abraded or fractured surface of the tree. A struggle then ensues between the tree and the fungus. The tree endeavours to cover up the wound by lateral growths of the ruptured bark; the fungus, by using up the protoplasm of the tree-cells in its growth, keeps the wound open, and even extends it. Canker, in the younger parts of an apple tree, proves fatal to them in the first season. This fungus also attacks, amongst other trees, the ash, elm, beech, and oak.

Certain fungi, like the mushroom and some of the moulds, live on dead or decaying organic matter, and are distinguished as **saprophytes** (Gr. *sapros* rotten; *phuton*, a plant). Others, like the canker just referred to, get their food from living plants, and in some cases from living animals, and it is these which are specially distinguished as **parasites.**

To the parasitic fungi some of the worst **diseases of crops** are due. Gooseberry mildew, the black scab of potatoes, the rusty blotches upon the straw of cereal crops, the dark powder that usurps the place of the grain in an ear of barley, the whitish covering that appears upon the leaves of cabbage and clover plants, and the blight that converts a crop of potatoes into an

evil-smelling mass of putridity, are some of the familiar effects of the work of parasitic fungi. The few fungal diseases of crops it is possible to notice here must be taken as types of many others.

RUSTS.—**Black Rust** (*Puccinia graminis*).—Upon the leaves and stems of wheat and other cereals, and also

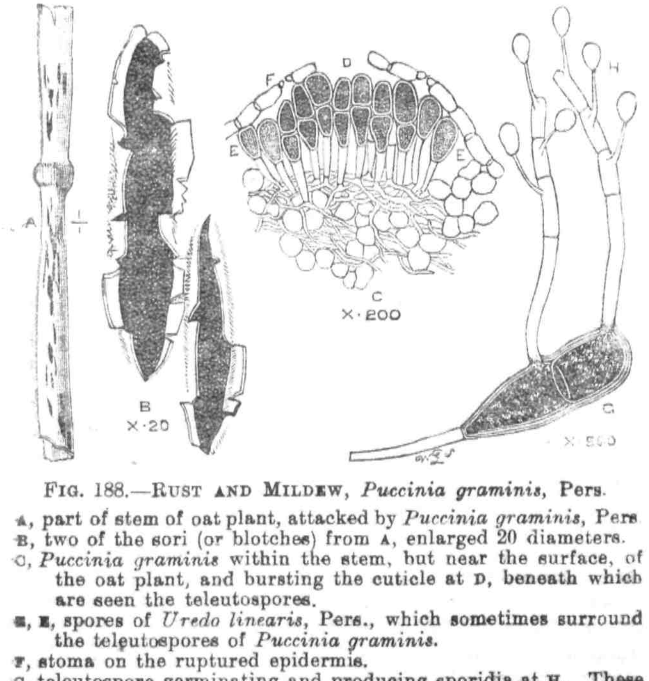


FIG. 188.—RUST AND MILDEW, *Puccinia graminis*, Pers.

A, part of stem of oat plant, attacked by *Puccinia graminis*, Pers.
B, two of the sori (or blotches) from A, enlarged 20 diameters.
C, *Puccinia graminis* within the stem, but near the surface, of the oat plant, and bursting the cuticle at D, beneath which are seen the teleutospores.
E, E, spores of *Uredo linearis*, Pers., which sometimes surround the teleutospores of *Puccinia graminis*.
F, stoma on the ruptured epidermis.
G, teleutospore germinating and producing sporidia at H. These sporidia on germinating give rise to *Æcidium berberidis*, Pers.

upon meadow and pasture grasses, brownish or blackish blotches (fig. 188), arranged more or less in lines, may frequently be seen. Look for them in the growing crops, and in the straw drawn from wheat and oat stacks.

In June and July close observation of wheat plants will often reveal the appearance of orange-yellow lines and spots upon the leaves. They rapidly increase in size and numbers, and, when the leaf is shaken, a coloured powder is set free. Under the microscope the powder is seen to consist of minute fungal cells—in a word, of spores. They are called **uredospores** (Lat. *uro*, to burn), in allusion to the rusty appearance they impart to the leaves and stems which are attacked. Their size is such that about a thousand of them, placed side by side, would measure one inch.

As the summer advances, the lines and blotches change colour, gradually becoming almost black. When rubbed, the leaves no longer yield the bright orange-coloured spores, but different ones of a much darker colour. Examined under the microscope, each of these spores is seen to consist of two thick-walled cells borne upon a single stalk. Because they appear later than the uredospores, these darker spores are called **teleutospores** (Gr. *teleutaios*, last). Both the uredospores and the teleutospores are produced by a mycelium which grows beneath the epidermis of the leaf and robs the plant of its nutriment, thus affecting the quantity and quality of the grain developed.

The minute uredospores are easily carried by the wind to adjacent wheat plants. Resting upon the moist surface of the leaf of such a plant, the uredospore germinates, and its hypha grows lengthwise till its free end finds its way through one of the numerous stomata (p. 158) into the inner tissues of the leaf. There, feeding upon the substance of the green cells, it forms a mycelium, the growth of which at length ruptures the epidermis (p. 386), and, in the brief space of two or three weeks, a new crop of uredospores is produced. Hence it appears that uredospores are capable of giving rise, first to a mycelium, and then to new uredospores.

The teleutospores behave differently. They usually remain unchanged for months, during which time they are lodged in decaying corn-stubble and in stacks. Early in the spring they germinate, and their hyphæ speedily produce minute egg-like structures which are called

sporidia. Unlike the uredospores, neither the teleutospores nor their sporidia appear to be capable of affecting the wheat-plant, and all attempts to produce rust by sowing the teleutospores upon the growing wheat-plant have failed.

If, however, the teleutospores should get carried in the spring, by the wind or any other agency, to the leaves of the barberry, which is a native British shrub, they germinate and produce sporidia. The latter send delicate tubes into the tissues of the barberry leaf, a mycelium develops, the leaf at the spot becomes swollen, and one of the forms of 'cluster-cup fungus' (an *Æcidium*) appears upon the under surface of the leaf, and produces numerous yellowish spores called **æcidiospores.** It has been satisfactorily proved that, when the æcidiospores of the barberry are sown upon the leaves of wheat and other gramineous plants, these spores germinate, infect the plant, and give rise to uredospores, followed by teleutospores. It is seen, therefore, that the æcidiospores are produced in the spring, the uredospores in the summer, and the teleutospores in the early autumn.

Where the æcidial 'host-plant' is absent, it is possible for the teleutospore stage to be suppressed, when compensation is made in the profuse production of the orange-coloured uredospores. This appears to be the case in Australia, of which country the barberry is not a native.

The facts just related were only obtained after many years of investigation. The three forms of fungus had previously been independently described, under the respective names of Uredo, Puccinia (after Puccini, a Florentine botanist), and Æcidium, and the wonderful relationship between them was not even suspected. It is obvious that the teleutospores of the Puccinia represent a **resting-stage,** by means of which the fungus is carried through the winter.

This organism affords an instructive example of a parasite which not only requires two different host-plants in order to complete its life-history, but which assumes a totally distinct form upon each host. To this

phenomenon the name of **Heterœcism** is given (Gr. *heteros*, different; *oikos*, a house). It is also called Metœcism.

It appears, then, that the agent which blotches, and blurs, and blackens corn crops consists of myriads of microscopic spores. To support the rapid vegetative growth whereby the fungus develops these spores much nutriment is required, and it is all taken from the host-plant. Hence the plant is unable to devote its full nutritive energy to the ripening of the grain, and so it happens that in badly infected corn crops the sample of grain is thin, shrivelled, and of inferior market value. In severe cases the straw may be so much discoloured as to be worthless; such straw should be burnt, and the ashes returned to the soil.

Corn crops grown on damp, low-lying lands suffer most from rust, and those of elevated lands come next in this respect. The mists in the lowlands and the clouds on the hill-tops are believed to be favourable to the development of the spores. The pest is also abundant on enclosed spaces surrounded by bushes and trees, which impede the currents of air; open wind-swept cornfields are less liable to attack. Wet, warm weather appears to greatly favour the fungus, and sometimes in England a field of grain which has been almost free from injury up to the beginning of the harvest month will, in the presence of much rain, suddenly begin to develop the spores with remarkable rapidity. In England a dry summer is usually marked by but little mildew. When cereal crops are free from mildew the straw is said to be 'clean.'

It is a matter of observation that rust is more likely to occur after heavy dressings of farmyard manure and nitrate of soda than after mineral manures alone. White wheats are more susceptible than are the more robust red varieties. The fungus is probably largely maintained by infected straw being used as litter, and afterwards spread out on the fields as manure; the uredospores find a congenial environment on the first young leaves of a corn crop, and the work of reproduction at once begins. Black rust also attacks barley, oats, and certain wild

grasses, but uredospores from one kind of plant are probably not able to infect other kinds of plant.

Yellow Rust (*Puccinia glumarum*).—This is the 'spring rust' that attacks wheat, barley, and rye, and may be distinguished from the preceding species not only by its earlier appearance, but by the paler colour of the streaks caused by the uredo stage. Its life-history is similar, except that no æcidium stage has so far been discovered, and the teleutospore stage is unnecessary; for the uredospores can remain dormant through the winter, after which they are able to infect the spring crop. Professor Biffen considers this species to be the commonest and most destructive rust.

Rusts are responsible for very serious losses among cereals in various localities. For example, in Prussia alone during 1891 the loss was estimated at £20,000,000, in round numbers. The breeding of varieties of cereals immune to rust is now found possible, and may in the end lead to the stamping out of this deadly kind of infestation.

Smut and Bunt.—A walk through a field of oats in June or July may often bring to view one or more ears which are covered with a dark powder. Gather such an ear, and shake the powder from it upon a piece of white paper. It will be found that the floral organs and their chaffy envelopes are quite destroyed, so that no grain can be formed. The powder is seen to possess a dark chocolate colour. It is made up of innumerable spores of the fungus (fig. 189) called **oat smut,** or *Ustilago avenæ* (Lat. *ustus*, burnt). The presence of much smut in a field of corn must lead to a considerable falling-off in the yield.

So small are the spores that a row of about 4,000 of them would not measure more than an inch, consequently they lie unseen in the irregularities upon the surface of an oat grain, and it is by the introduction of spores through the medium of grain used for seed that a crop of oats becomes infected.

Wheat smut (*U. tritici*, Jens.) and **barley smut** (*U. nuda*, Jens., and *U. tecta*, Jens.) do not, if recent researches are confirmed, cause infection through the

agency of the grains, but attack the delicate flowers of fresh victims.

In the ground the spores germinate at about the same time as the oat grain on which they rest. Whilst the germinating embryo of the grain is extremely soft and tender, a delicate tube emitted by the spore penetrates the young cells of the former. Once established within its host-plant, the fungus develops its mycelium, which grows as the host grows, making its way from cell to cell without betraying any outward sign of its presence. The parasite may thus thrive for months within an apparently healthy plant. At length a time comes when the long waiting of the fungus is, as it were, rewarded. This is precisely at the period when the oat plant is prepared to concentrate its energies upon the maturation of the grain. Then it is that the parasite assumes new vigour, develops a dense network of hyphæ within the young grain, and makes use of the nutrient juices of the host-plant for the production of countless spores. Usually all the ears upon one

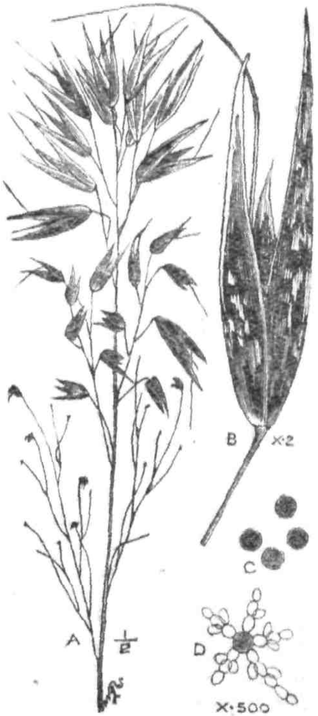


FIG. 189.—SMUT OF OATS, *Ustilago avenæ*, Jens.

A, panicle of oats attacked from below upwards.
B, spikelet, with the fungus in an early stage of growth.
C, free spores.
D, spore germinating and producing yeast-like buds.

plant, and all the grains in the same ear, are destroyed. The spores crowd thickly upon the ear, and as they become detached they settle upon the ripening grain of healthy plants, and there they may perhaps remain until such grain is used for seed purposes, when the series of changes that have been described are liable to be repeated. Smutted ears are not seen at harvest time, for long before then all spores will have been blown away, and only the bare rachis, or floral axis, will remain.

The effect of sulphate of copper, or other antiseptic agents sometimes used, is not to destroy the spores of the fungus, which, indeed, live through the application; but when the spores germinate the delicate young hyphæ find themselves in a medium which is fatal to them, and the disease is thus checked. By persistent 'pickling,' season after season, it is possible to reduce very materially the loss of yield which would otherwise result through the activity of the smut fungus.

Suitable pickling solutions are (1): 1 lb. of copper sulphate to 1 gallon of water for 4 bushels of grain; (2) 1 pint of 40 per cent. formalin to 36 gallons of water for 40 to 50 bushels.

The former liquid is poured over the seed grain heaped upon the barn-floor, and the grain is turned several times with a shovel. This is done the day before sowing, and as the water evaporates a thin coating of the sulphate is deposited upon the grain. When formalin is used the grain is put in a bag and steeped for ten minutes in the solution. It may be added that by immersing seed oats for five minutes in water at a temperature of 127° F. to 133° F. the vitality of the seed is not impaired, but smut is prevented.

Pickling wheat and barley, in order to check the ravages of their particular smuts, is useless if the researches already mentioned (pp. 390-1) receive confirmation.

Closely allied to the smut fungus is the parasitic organism *Tilletia Caries*, which produces **bunt** in corn. In this case, however, the grain is converted into a dark

greasy mass with a foul fish-like odour. As the injured grains are harvested with the rest of the crop, there results a bunted sample of corn, the flour from which can only be used for inferior purposes. Smut is easily seen in the field, but the detection of bunt demands a more experienced eye. The offensive greasy material inside the affected grains consists of the spores of the fungus, and as these escape in the subsequent treatment of the grain, a few bunted specimens may infect a large number of grains. The general life-history of bunt is very similar to that of oat smut. In this case also, therefore, it is desirable to dress the seed grain before sowing.

In this country bunt appears to confine its attacks to wheat and barley, whilst in other lands maize also suffers. Smut is of more general occurrence, and attacks not only wheat, barley, oats, and rye, but various grasses, especially tall oat grass. Smutted ears should be gathered and burnt.

Ergot (*Claviceps purpurea*).—From early in July onwards examine the grasses that grow in or alongside the watercourses. It is probable that some will be found to have dark-purplish spur-like structures (fig. 190) upon the panicles. These are specimens of **ergot**, this name being the French word for cock-spur.

When ergot has been once seen it is always easy to recognize it again, and it may be looked for in meadows and pastures, and also in cornfields. The ergot of rye is one of the best known forms, but the structure occurs also upon other cereals, and upon most of the cultivated and many of the weed grasses. It is occasionally found growing upon other than gramineous plants—upon sedges, for example.

The dark spur-like outgrowth is known as the **sclerotium** stage (Gr. *skleros*, hard) in the life-history of this fungus. It is really a resting stage, for it is the form in which the organism is carried over the winter. As the sclerotia ripen they fall to the ground during the autumn, and remain unaltered till the early summer. Then, under the influence of moisture and higher temperature, certain changes—which need not be described

here, but some of which are indicated in fig. 190—take place, resulting finally in the production of a very large number of exceedingly delicate spores, which, being long and narrow, are described as needle-shaped or thread-like. They are formed in numbers of delicate tubes (*asci*), each producing six to eight spores, which are termed *ascospores* (Gr. *askos*, a bag, a flask).

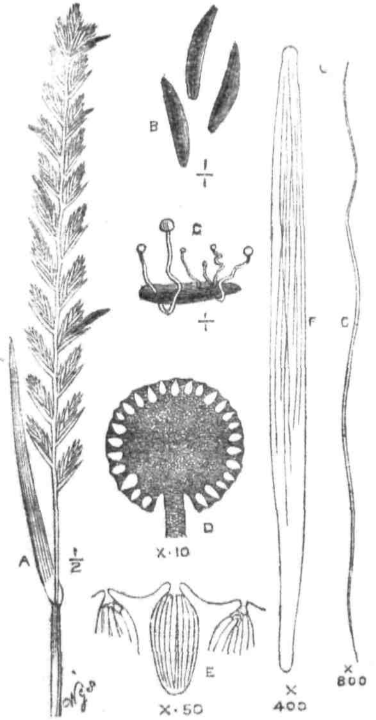


FIG. 190.—ERGOT,
Claviceps purpurea, Tul.

A, rye grass ergoted.
B, free ergots, or sclerotia, natural size.
C, sclerotium germinating.
D, one of the heads (magnified) from C, showing perithecia imbedded near the circumference.
E, a single perithecium showing its mouth and enclosed asci.
F, a single ascus from the perithecium, showing the linear ascospores, or sporidia, within.
G, a single ascospore or sporidium.

This happens at about midsummer—just at the time, that is, when most of the grasses are in flower. The light delicate ascospores are easily wafted on the breeze, or transported by rain or insects. Some of them fall upon the flowers of cereals and grasses, and there they at once begin to germinate, and as the result the lower parts of the flower become invaded by a mycelium. In the course of ten days or a fortnight, the mycelium sends out delicate hyphæ, which

form a network upon the pistil, and from which thousands of minute **conidia** (Gr. *konis*, dust) are set free. At the same time there is secreted a thick sweetish liquid, in which the conidiospores are bathed. This is known as the 'honey-dew' stage of the disease. Insects carry the sticky fluid from one grass flower to another, and the conidia are thus easily spread. On a fresh flower the conidia germinate, cause the secretion of more honey-dew, and a new crop of spores is produced.

Ultimately the formation of honey-dew ceases, and a dense hard network begins to appear, the remnants of the destroyed ovary being still discernible at the free end. This network grows into the sclerotium; it is larger than the grain of the plant which it infests, and it is mature at about the time the surrounding corn is ready for harvesting.

The honey-dew and the sclerotium were formerly thought to be distinct kinds of fungus, and received separate names, in the same way as did the different stages of rust.

Ergot is regarded as a dangerous pest, because it is believed to be capable, under certain circumstances, of causing cows to slip their calves—that is, to give birth to them prematurely—much loss thereby arising. Ewes and other animals are similarly affected by it.

Ergoted grasses should be collected and burnt, in order to destroy the sclerotia. Grass seeds ought always to be examined for ergot, and, if any should be present, the sample ought not on any account to be sown.

American Gooseberry Mildew (*Sphaerotheca mors-uvae*, Berk. et Curt, fig. 191), which is now a notifiable disease, first appeared in Europe (Ireland) in 1900, and has since spread with alarming rapidity. When the leaf-buds open in spring it may be seen upon them as a whitish 'mildew,' which later on assumes a powdery appearance owing to the formation of innumerable conidia, and gradually spreads to the young wood and fruit. As winter approaches it becomes darker in colour, and is then found on the ends of the shoots, which look dark and shrivelled. When examined with a lens numerous

blackish spots (the 'winter fruit') can be seen. These are hard capsules, in which are produced the spores by which the fungus will be spread in the following season. Though spraying with Bordeaux mixture and some other preparations is found useful for combating the spring stage, the well-protected winter condition is not amenable to treatment, and the wholesale destruction of infected bushes is found to be necessary.

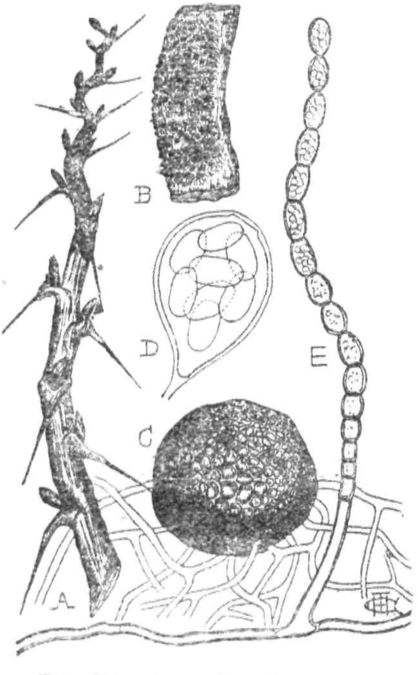


FIG. 191.—AMERICAN GOOSEBERRY MILDEW.

A, gooseberry twig, the upper part attacked and distorted by the fungus.
B, part of same, enlarged, showing the fungus.
C, globular body (*perithecium*) with the mycelium.
D, sac (*ascus*) with eight spores.
E, conidia of mildew stage.

POTATO DISEASE.—The characteristics of the potato disease are well known in most parts of the country. Although the total area under certain other crops is greater, the potato is probably the most generally cultivated of all crops, for it always finds a place in kitchen gardens and in allotments. The blackening and shrivelling of the haulm proclaims to the eye, and a very distinctive odour to the nose, that

the potato disease fungus is busily at work, and when the crop is lifted the tubers may afford evidence of all stages of decay, from a slight attack to thorough rottenness. Immense sums of money have been lost, and great suffering has arisen at times, as in the year 1845 in Ireland, through the partial or total failure of the potato crop. The fungus (fig. 192) associated with the disease is called *Phytophthora infestans* (Gr. *phuton*, a plant; *phthora*, decay, destruction).

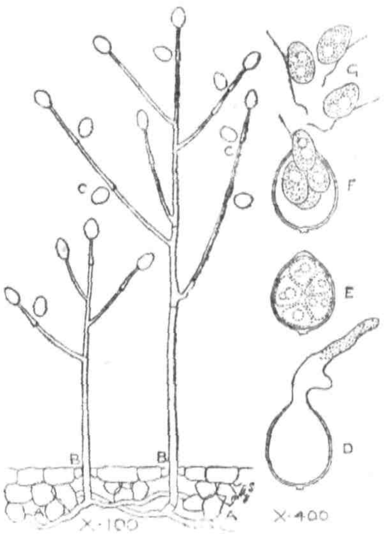


FIG. 192.—POTATO DISEASE FUNGUS, *Phytophthora infestans*, De Bary.

A, part of interior of lower surface of potato leaf, showing mycelium of potato fungus ramifying amongst the cellular tissue of the leaf.
B, branches of fungus emerging through stomata.
C, conidia.
D, conidium germinating and producing mycelium.
E, another conidium, its contents differentiating into zoospores.
F, conidium opening, and emitting zoospores.
G, free zoospores.

Examine the under surface of the leaf of a potato plant in the early stage of the disease. Notice the brownish spots, with a delicate silky material round their margin. The spots are destroyed tissue and the silky material consists of the hyphæ of the infesting fungus. By the aid of a magnifying glass a whitish powder may be seen amongst the interlacing hyphæ. This is made up of

myriads of minute spores. The atmosphere becomes laden with such spores, some of which cannot fail to get deposited upon the leaves of healthy potato plants.

Suppose a spore to fall thus upon the leaf of a plant hitherto free from disease. Provided only the merest film of moisture be present, the spore bursts at its narrower end, and there emerge from it about ten smaller spores (called **zoospores**) formed of the protoplasm which occupied the interior of the parent spore. Each zoospore swims about actively by means of two delicate whip-like filaments or flagella (Lat. *flagellum*, a whip). In less than an hour it comes to rest, loses its cilia, assumes a spherical shape, and presently develops a delicate hypha, which either bores through an epidermal cell of the potato leaf or enters at one of the stomata (fig. 192). In either case the hypha reaches the active green cells of the leaf, in and amongst which it develops a mycelium, with the destructive effects already described.

The leaf, it will be remembered, is the organ (p. 158) in which starch is manufactured, but the factory is completely deranged by the growth of the potato-disease fungus. This, however, is not all. The tuber is a reservoir in which the plant stores up starch. Not content, as it were, with destroying the starch factory in the cells of the leaf, the hyphæ of the fungus extend along the tissues inside the stalks of the plant, and at length reach the great store of starch in the tuber. The mischief done in the tuber will vary with circumstances. The starch may be consumed, and the tuber may be converted into a rotten mass whilst still in the ground. On the other hand, very little progress may be made with the destruction of the tuber, within which it is possible for the mycelium to hibernate. Hence an apparently sound tuber may contain within itself the germs of disease, and, if such a tuber is used for seed purposes, the fungus will develop, and the young plant will become a new centre of infection. Tubers for seed should, therefore, never be saved from a crop in which disease has been detected. In general practice it is

better to use for seed those kinds which appear to suffer least from the disease.

The haulms from a diseased crop should be gathered together and burnt, and rotten tubers should also be put in the fire, so as to ensure the destruction of all spores and hyphæ. The refuse of the crop should *never* be thrown upon the manure heap.

Spraying with Bordeaux mixture, which is a weak solution of sulphate of copper (blue-stone) containing quicklime, has proved a very effective mode of treatment. The ordinary mixture consists of 12 lb. of copper sulphate and 8 lb. of fresh quicklime in 75 to 100 gallons of water. From 100 to 150 gallons per acre is generally employed.

The production of spores by the mycelium of *Phytophthora infestans* is dependent upon temperature. Below 40° F. and above 78° F. no spores are formed. About 72° F. is the most favourable temperature. The climate of the British Isles is such that a mean temperature of 78°, or higher, cannot be looked for, otherwise potato disease would be less prevalent. But if the closely allied tomato (p. 214), grown under glass, should be attacked, as it sometimes is, the maintenance in the glass-house of a temperature not below 78° should check the progress of the disease.

Moisture is, as has been stated above, an indispensable condition to the spreading of the spores. Rain, therefore, helps them to travel along the leaf, and to find their way down the stem. It also washes them into the soil till they reach the growing tubers, which, through their delicate skins, are easily infected. Much disease originates in the last-named manner. Potatoes grown in sandy soils suffer less, as a rule, from the disease than those grown in heavy soils. The reason is that sand is a more effective filter, and thus waylays the spores as they trickle down in the rain-water. The heaving of the soil produced by the expansion of the tubers in their growth leads to the formation of cracks and fissures in a clay soil, down which the spores can readily travel. A sandy soil, on the other hand, is continually accommodating itself to the pressure from the

tubers, and does not form cracks, whilst the trickling of water serves still further to pack the particles together, and thereby to obstruct the passage of the spores. In the system of cultivation known as *high moulding*, the crop is moulded up a second time, as late before the appearance of disease as the growth of the haulms will permit. A depth of not less than four inches of soil is sufficient to prevent the spores from reaching the tubers, and it fills up the cavity at the top of the soil caused by the oscillation of the stems in the wind. If the moulding is brought to a pronounced ridge, the spore-laden rain-water will flow down into the hollows, where the spores can germinate without affecting the tubers.

Great loss of potatoes is caused by **after-sickness.** Tubers that are perfectly healthy when lifted may yet contract potato disease in the harvest field. When freshly dug, the potato has a skin which is tender enough to be penetrated by the hyphæ of the conidiospores, and there is usually sufficient moisture to permit the germination of conidia, if present. The risk of after-sickness is greatest amongst the sound tubers of a diseased crop. To prevent it, the crop should not be dug till all the haulm is dead. Should such delay be impracticable, the haulms should be pulled up and removed from the ground before the potatoes are lifted; so long as they remain in the ground the sound tubers are safe from the disease, but when they are brought into the air, which is laden perhaps with conidiospores, the tubers can hardly escape infection.

Though largely dependent on season, the potato disease develops much more readily in tubers grown by the use of highly nitrogenous manures, and containing a juice rich in nitrogen, than in those grown under ordinary conditions.

White Rust.—On shepherd's-purse, one of the commonest cruciferous weeds of waste places, there may often be noticed a whitish streak, such as would be left by whitewash. This is the 'white rust,' and it is due to the presence of a fungus (fig. 193) called *Cystopus candidus*. In kitchen gardens, cabbages and cauliflowers

are frequently thus affected, whilst turnips and most other cruciferous plants are likewise liable to attack. The mycelium of this fungus invades all parts of the host-plant above ground, and, if a crop is attacked in its seedling stage, it may be swept away altogether.

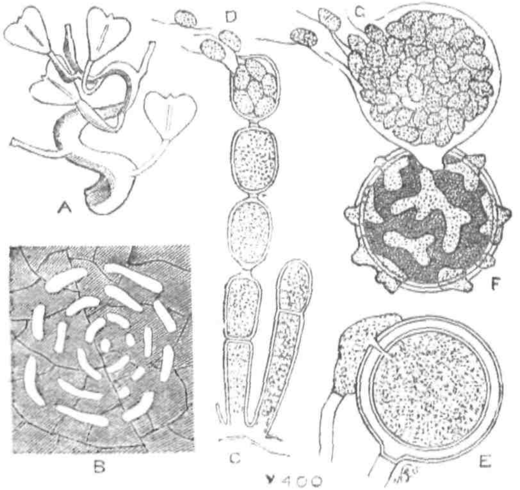


FIG. 193.—WHITE RUST, *Cystopus candidus*, Lev.

A, fruiting stem of shepherd's purse, swollen and distorted by *Cystopus candidus.*

B, fragment of cabbage leaf with *Cystopus candidus* growing in a concentric manner.

C, a short chain of conidia of *Cystopus candidus*, the top one producing zoospores, D.

E, globular oogonium with antheridium attached (sexual stage).

F, oospore or resting spore, producing zoospores at G.
(A and B natural size; the others × 400 diameters.)

The minute spores of *Cystopus candidus* are readily carried by the wind and other agencies, and the infection may thus be rapidly spread. The fungus is preserved through the winter by means of resting spores,

which lurk in decaying fragments of cruciferous plants, or in the soil itself.

The obvious means of dealing with this pest are to burn the refuse of diseased cruciferous crops, to give the land two or three years' change from such crops, and to suppress cruciferous weeds.

DAMPING OFF.—What gardeners term the 'damping off' of seedlings is the work of a fungus—of a species of Pythium (Gr. *putho*, to rot, to decay). It is often seen in mustard and cress, especially when these are sown too thickly, so that a free circulation of air is prevented. The spores are in the soil, and, when they germinate, their hyphæ bore into the seedling plants in the region between root and leaves, and weaken them to such an extent that they topple over. Each young plant thus attacked becomes a centre of infection, from which the disorder spreads. Besides cruciferous plants, others, such as white clover, spurrey, etc., fall victims to this pest.

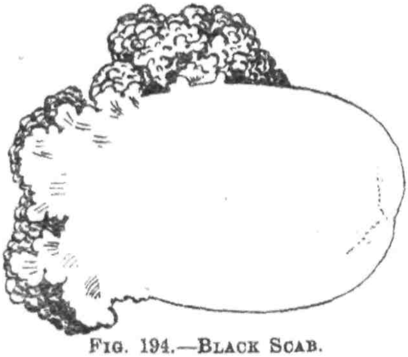


FIG. 194.—BLACK SCAB.

Land upon which the 'damping off' of seedlings has recently occurred, should not be sown with similar seeds for a considerable period afterwards.

BLACK SCAB OR WART DISEASE (*Chrysophlyctis endobiotica*, fig. 194) is a notifiable disease which has caused serious damage to potatoes during the last few years, especially when they are grown continuously, as in gardens. The disease is first visible in the form of warts or ridges, situated near the 'eyes' of the tubers, which increase in size and fuse together, ultimately forming

black spongy outgrowths of characteristic appearance. Examination of thin sections under the microscope shows that the fungus consists of isolated rounded cells, within which spores are formed (fig. 195). These are of two kinds: (a) *zoospores* (*see* p. 398), which make their escape and spread the disease during the cropping season, and (b) *resting spores*, which remain dormant through the winter, or it may be for a longer period (up to four years).

Diseased tubers should be burnt, and must never be employed for seed. If the crop has been grown in

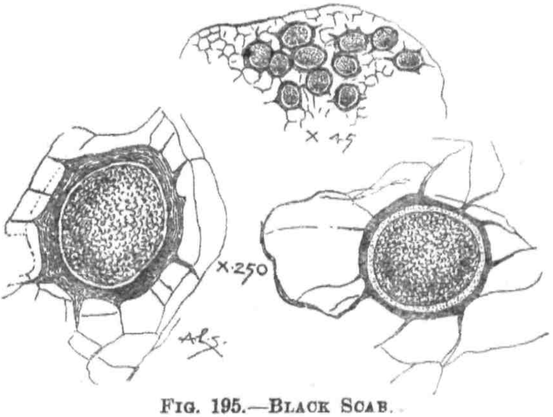


FIG. 195.—BLACK SCAB.
Spore-producing cells, magnified.

a rotation it should be replaced by some other crop when it is next due, while in the case of continuous growing at least one season should elapse before potatoes are again planted, and the soil disinfected with gas-lime or powdered sulphur.

CLUB-ROOT in turnips, cabbages, cauliflowers, rape, and other cruciferous crops (p. 179) is the name given to a malformation of the roots. When pulled, the main root is found to be much dwarfed, whilst the side roots are often swollen into spindle-shaped masses, presenting

an appearance to which the name of finger-and-toe is appropriately applied. Lumps or nodules may also be seen upon the root. A crop thus affected ultimately perishes, owing to the decay of the roots.

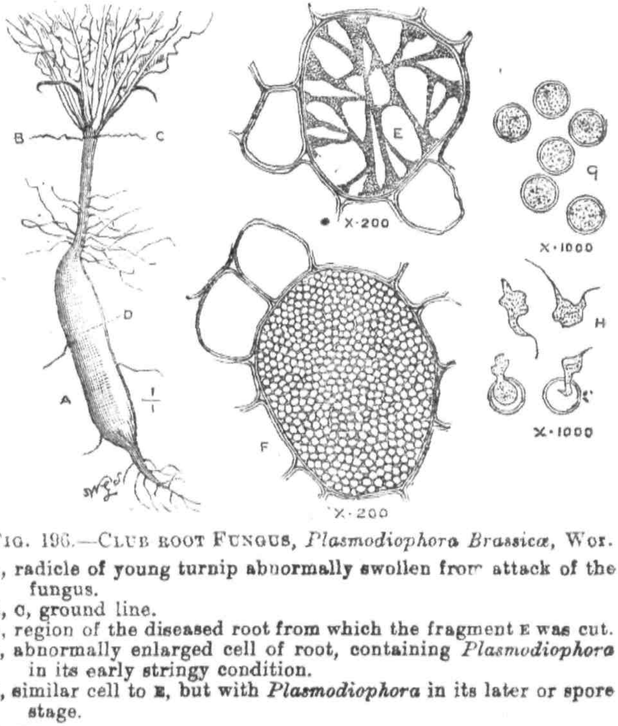


FIG. 196.—CLUB ROOT FUNGUS, *Plasmodiophora Brassicæ*, Wor.

A, radicle of young turnip abnormally swollen from attack of the fungus.
B, C, ground line.
D, region of the diseased root from which the fragment E was cut.
E, abnormally enlarged cell of root, containing *Plasmodiophora* in its early stringy condition.
F, similar cell to E, but with *Plasmodiophora* in its later or spore stage.
G, spores.
H, spores germinating and producing amœba-like zoospores, usually with one flagellum (or whip-like filament).

This disorder is associated with the presence of a slimy fungus (fig. 196), known as *Plasmodiophora Brassicæ*. The spores of this organism are exceedingly minute, and they not only attack and destroy cruciferous

crops, but they infest the soil to so great an extent that it is unwise to grow such crops upon the same land again for several years. A spore, existing in the soil, finds its way into a cruciferous plant through a root-hair, and at once makes a demand upon the protoplasm of the plant. The spores produce slimy masses called **plasmodia**, and these creep from cell to cell of the infested plant.

The refuse of a diseased crop should not be left in the field nor thrown upon the dung-heap, for in either case it is capable of serving as a new source of infection. Dressing the land with lime has the effect of destroying spores in the soil.

This disorder, by whatever name—*club-root*, *finger-and-toe*, or *anbury*—it may be called, must not be confused with a malformation of the root, which occasionally arises as the result of some peculiarity in soil, seed, or manure, and is really a case (p. 473) of 'reversion' to the wild type. In such instances the growths, though distorted, are nevertheless healthy, but, when the fungus is present, it is only necessary to cut across the root in order to see that the latter is filled with decaying matter.

Nor, again, should the wart-like growths formed upon the root by the small beetle called the turnip-gall weevil (p. 620) be mistaken for the work of the fungus. By cutting across such galls on the roots of turnips and cabbages the legless maggots of the insect may be found.

BACTERIA.—The **wet rot** of potatoes is due to certain species of bacteria (chiefly *Clostridium butyricum*), as are also **turnip white-rot** (*Pseudomonas destructans*, Potter) and **cabbage black-rot** (*P. campestris*, Smith). Bacteria, however, produce but very few plant diseases, though they are the cause of most infectious or contagious diseases of animals, such as anthrax, tuberculosis, and pleuro-pneumonia.

The delicate tube-growths (hyphæ) of the parasitic fungi which attack flowering plants exhibit, as has been seen, two marked differences in their **mode of development.** Either their growth is confined to the immediate neighbourhood of the point of attack, or else it spreads

widely or unlimitedly from that point over and through the host-plant. The rust fungi are admirable examples of the first kind. Each distinct spot upon a grass or cereal plant inhabited by the fungus is the result of the growth of one spore, or occasionally of several, which have come together by mere accident. Fresh spots are added one after another on a surface, in proportion as new spores from any quarter—for instance, from those first established on the leaf—germinate there and assail it. Ergot is another good example of the first class; its attacks are always confined to the ovary of the host. To the second category belongs, for example, the potato-disease fungus; the delicate tubular growth resulting from the germination of a single spore will find its way into the tissues of the potato plant, and may continue to grow till the whole plant is permeated with the fungal threads, which here and there break through the epidermis of the leaf and produce spores. The smut fungus, again, ramifies through the entire plant, though its external eruption is confined to the ear of the grass or cereal which it attacks.

The **methods of suppression** directed against fungus pests are based upon a knowledge of the life-history of each injurious organism. The general rule is to ascertain the cycle of changes through which the organism passes, and then to attack it at its weakest point. Thus, in the case of ergot, it is recommended to burn the pest in the resting stage represented by the sclerotium. The suppression of weeds, especially of those which are allied to cultivated plants, and which probably harbour the spores of the same fungi as those to which the cultivated plants fall victims, is specially called for.

Independently of such considerations, however, the practices of what may be called **good farming** are opposed to the thriving of parasitic fungi. The plants most liable to attack are the weakly and backward ones. Thorough tillage, liberal manuring, and similar precautions, will frequently serve to carry a crop beyond the risk of attack, inasmuch as a healthy and vigorous growth imparts to the plant a capacity for resisting the insidious advances of parasitic fungi.

PART III.—THE ANIMAL

CHAPTER XIX.

STRUCTURE AND FUNCTIONS OF FARM ANIMALS

THE live stock of the farm, excluding poultry, comprises horses, cattle, sheep, and pigs, all of which are bred and reared by the farmer, so that it is of practical importance for him to learn something about their structure and functions.

Horses, cattle, sheep, and pigs belong to that group of animals termed the Vertebrata, all of which possess a backbone. Of Vertebrata there are five classes—mammals, birds, reptiles, amphibians, and fishes. It is in the first of these, the class **Mammalia,** or *hot-blooded, hair-clad animals which suckle their young*, that horses, cattle, sheep, and pigs—as also men and dogs—are included.

The study of the structure of animals is known as Anatomy. The study of the uses or functions of the various organs is termed Physiology.

Horses, cattle, sheep, and pigs, although so easily distinguished by outward appearance, are yet closely similar in their general structure and in their physiological characters. These statements equally apply to men and dogs, which also, in a sense, belong to the farm. Hence, it is not necessary for us to study each animal individually and exclusively, but one may be taken as the type of all. **The horse** is here taken as the type, special reference being made to the other animals only when they differ markedly from it.

REGIONS OF THE BODY.—A broad distinction may be drawn between body and limbs. The former is divided

into head, neck, trunk, and tail, while the fore and hind limbs are attached respectively to the front and back of the trunk. The upper surface of the body is conveniently termed **dorsal**, and the under surface **ventral**, while **anterior** and **posterior** technically replace the ordinary words front and back.

In the trunk of a mammal there are two regions. The anterior one is the **thorax** or chest, and the posterior one the **abdomen** or belly—spoken of as the 'barrel' in a horse. The thorax is completely separated from the abdomen behind by a transverse partition called the **diaphragm**, and, though certain tubes—the gullet and some of the blood-vessels—pierce the diaphragm, their passage does not establish any communication between thorax and abdomen.

When the thorax is opened, it is seen to contain the heart, with the lungs on either side of it. The heart is the organ whereby the circulation of the blood is effected. The lungs, called 'lights' by the butcher, are concerned in the work of respiration or breathing.

When the abdomen is opened, the chief organs seen at first are the stomach and intestines. By turning the latter on one side, it is possible to bring into view the liver, the kidneys, and certain other organs.

The Skeleton.—If a horse were divested of all its soft parts, there would be left a bare framework of bone, gristle, and fibrous tissue, called the *skeleton*, which supports or carries all other portions of the body.

The skeleton (fig. 197) is made up of an **axial** part and an **appendicular** part, the former including *skull*, *backbone*, *ribs*, *breast-bone* (*sternum*), while the latter comprises the skeleton of the appendages or limbs. The fore-limbs join, or *articulate*, to the axis by means of a *shoulder-girdle*, the hind-limbs by means of a *hip-girdle*.

The **backbone** is often termed the *vertebral column*, because it is really a chain of bones, each of which is called a **vertebra**. Each vertebra is a ring, of which the dorsal part is the *arch* and the thickened ventral part the *body*. When the vertebræ are placed end to end they form a tube, which, as it contains the great nervous

axis—the spinal cord—is called the **neural canal.** In the living animal, the bodies of the vertebræ are not actually in contact, there being between each pair an elastic pad or cushion, consisting of **gristle** or **cartilage.** Hence,

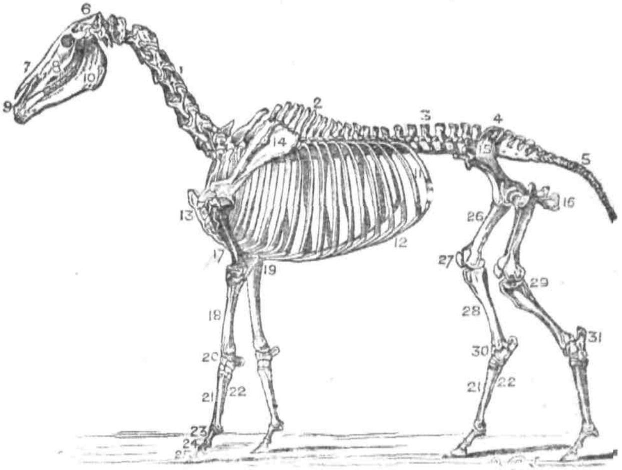


FIG. 197.—SKELETON OF HORSE.

1, cervical vertebræ.
2, thoracic vertebræ.
3, lumbar vertebræ.
4, sacral vertebræ.
5, caudal vertebræ.
6, parietal bone.
7, nasal bone.
8, maxillary bone.
9, premaxillary bone.
10, mandible.
11, ribs.
12, costal cartilages.
13, sternum.
14, scapula.
15, ilium.
16, ischium.
17, humerus.
18, radius.
19, olecranon process of ulna.
20, carpus (knee).
21, cannon bone.
22, splint bone.
23, pastern.
24, coronet.
25, coffin bone.
26, femur.
27, patella (stifle joint).
28, tibia.
29, fibula.
30, tarsus (hock).
31, calcaneum (heel bone).

the backbone as a whole possesses some degree of pliancy, as is seen when a cat arches its back or a man stoops to the ground.

The backbone comprises several *regions*. In the horse, as in nearly all mammals, there are seven **cervical** or **neck** vertebræ. These are succeeded by eighteen **thoracic** or **chest** vertebræ, which support the ribs, and are above the chest or thorax. Next come six **lumbar** or **loin** vertebræ; then five **sacral** vertebræ, fused together into one piece, the *sacrum*; and finally about seventeen **caudal** or **tail** vertebræ within the tail.

The **neck vertebræ** of the horse are almost cubical. Above them pass the *ligaments* of the neck, strong fibrous bands which hold up the head. The first neck vertebra, or **atlas,** is an oval ring, on the anterior side of which are two deep cups that fit on to two corresponding knobs (*occipital condyles*) on the back of the skull, constituting a hinge-joint, that renders nodding movements possible. The second neck vertebra, or **axis,** is also exceptional in character. A blunt peg (*odontoid process*) projects from the front of its body through the cavity of the atlas, and is attached to the back of the skull. The head and atlas can be moved from side to side round this peg, which serves as a pivot. The arrangement is, in fact, a *pivot joint*. The **chest vertebræ** possess bony spines which extend upwards, the longest ones being at about the middle, and each such vertebra supports a pair of ribs. The loin vertebræ have large flat lateral projections, which are well seen in a 'saddle' of mutton. In the adult horse, the five **sacral vertebræ** are fused together into one bony piece called the *sacrum*, which supports the hip-girdles. In the sacral and in the succeeding **caudal vertebræ** there is no continuation of the neural canal. The caudal vertebræ are, indeed, reduced to solid bony cylinders.

At its anterior end, the central bony axis is greatly modified, and takes the form of the **skull.** The tube or canal, which extends along the backbone, here expands into a large cavity, surrounded by bone; this is the *cranial* part of the skull, constituting the **brain-case** or **cranium,** which lodges the brain. A still larger portion is seen in front and below, and comprises the **facial** part of the skull. The side-walls and roof of the

cranium are made up of flat thin bones, chiefly the *parietal* bones at the sides, and the *frontal* bones in front, extending above and between the eyes. Much of the front part of the face is supported by the *nasal* bones, which are long flat triangular bones roofing in the cavities of the nose. On either side of the nasal bones are the *maxillary* or upper jaw bones, which carry the upper grinding teeth (premolars and molars). Extending forward, and carrying the upper cutting teeth (incisors) are the two *premaxillary* bones. Two large flat bones, right and left, make up the powerful lower jaw, or *mandible*, in which the lower teeth are imbedded. They are fused together in front, and diverge from each other backward, at length articulating by a convex projection (*condyle*) each side with the upper part of the skull.

Of the eighteen pairs of **ribs**, the flattest are in front, and those most arched are behind. Each rib is made up of a bony part above and of a gristly or cartilaginous part below, this gristly part being called the *costal cartilage* (Lat. *costa*, a rib). In the first eight pairs of ribs, each costal cartilage communicates separately and independently with the sternum, or breast-bone, below—these are called *true ribs*. In the remaining ten pairs of ribs the cartilages run together, as it were, and only in this way become attached to the sternum; these are called *false ribs*.

The **sternum**, or **breast-bone**, of the horse is narrow and keel-like. The sternum of the ox, on the other hand, is broad and flat, and imparts to that animal the broad-chested appearance seen above the dewlap.

Each **shoulder-girdle** of the horse is very simple, consisting merely of a *shoulder-blade*, or *scapula*. The fore-leg of the horse is restricted in its movement, being capable only of a motion backwards and forwards. It cannot move sideways, so that there is no necessity for a *clavicle* or *collar-bone*, such as exists in man, but is absent in the horse. The scapula on each side is slender, and has at its lower extremity a shallow cup (*glenoid cavity*), in which the head of the upper-arm bone (*humerus*) works. A bony *ridge* extends along the outer face of the

scapula. The ridge is thickened and turned *backward* above the middle, so that it is always easy to determine whether a separate shoulder-blade belongs to the right side or to the left.

Each **hip-girdle** of the horse is less simple and more complete. It consists of an *innominate bone* (*os innominatum*), made up of three parts, which are distinct in the young animal, but fuse into one piece as age advances. The large triangular bone which extends forward, and the rough extremity of which projects so prominently in a lean animal, is the *ilium*, pin-bone, or haunch-bone. The bone extending backward to the side of the tail is the *ischium*. The flat bone beneath, joining with its fellow in the middle line, is the *pubis*, the place of union of the two pubic bones being called the *symphysis pubis*. The three elements of the innominate bone —ilium, ischium, and pubis—all meet together in a deep cup, the *acetabulum*, into which the head of the thigh-bone (*femur*) fits. The two ischia do not meet above, although they incline towards each other, the sloping surfaces resting one on each side of the sacrum. Hence, looked at below from the front, the hip-girdles, with the sacrum, form a complete bony ring or basin (the **pelvis**), which is much more capacious in the female than in the male. The long axes of the hip-girdles, on which depends the relative size of the 'quarters' in a horse, form an acute angle with the vertebral column.

The **limb-bones** of the horse can be best understood by comparing them with the corresponding bones in man. Place the hand on the bone which extends from the shoulder to the elbow; this is the **humerus**, or upper-arm bone. The humerus of the horse can easily be felt, but it is hidden beneath the skin; nevertheless, when the horse walks, the movements of the humerus are at once noticeable.

Lay your left forearm flat on the table, with the palm of the hand facing upwards. This is the *supine* position; and the thumb is on the outer side. Feel the two parallel bones which extend from the elbow to the wrist—the one on the thumb side is the **radius**, the other one is the **ulna**. These bones are separate throughout their entire

length, so that the radius, bearing the wrist and hand, may be made to rotate round the ulna. Without moving the elbow, turn the left hand completely over. Its palm will now face downwards, and the thumb, as well as the lower end of the radius, will have described half a circle, so that the radius and ulna, instead of being parallel, will now be crossed. This is the *prone* position, and the thumb is now on the inner side. At the elbow joint, the ulna can be felt to project backwards, forming the *olecranon process* (the so-called 'funny-bone') of the ulna.

The fore-limb of the horse contains the same two bones—ulna and radius—as the forearm of man. But, in

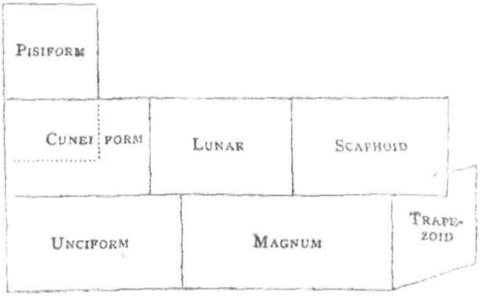


Fig. 198.—Diagrammatic View showing the Positions of the Bones in the Carpus, or 'Knee,' of the Horse.

the horse, the ulna, though it has a prominent olecranon process, dies away, and terminates in a button-shaped end rather more than half-way down the radius. The two bones are immovably united together, and the fore-arm is permanently fixed in the prone position.

In the horse, the region popularly termed 'the knee' corresponds with the **wrist** of man. The anatomical name is the **carpus**, and it consists of an upper and a lower row of *carpal bones*. Suppose the carpus of the 'off' fore-leg of a horse (*i.e.*, the right limb) to be viewed from the front, the names and positions of these bones are indicated in the diagram (fig. 198).

There are, as the diagram indicates, three bones in the upper row and three in the lower row. An additional bone (the pisiform) projects at the back of the carpus. It is an example of the class of *sesamoid* bones, which are developed within tendons, the strong fibrous cords by which muscles are fixed to bones. Each bone has smooth joint surfaces, and is provided with delicate membranes which secrete lubricating 'joint oil,' or synovial fluid. The whole arrangement is such as to constitute entire security against concussion. At the same time it permits the animal to use the fore-limbs freely without risk of fracture, even when drawing heavy loads, or carrying considerable weight in the saddle at great speed.

The 'foot' of the horse is merely a remnant of the foot as it existed in the extinct form of the ancestors of the horse. Its bony framework will be best understood by comparison with the hand of man. Lay the left hand on the table, and notice the five digits—I., thumb; II., forefinger; III., middle finger; IV., ring finger; V., little finger. Feel the back of the palm, and notice that at the base of each digit there is a long bone extending between the digit and the carpus or wrist. These are the **metacarpals** or **palm-bones,** and they may be referred to as metacarpal 1 (from wrist to thumb), metacarpal 2 (from wrist to forefinger), etc. The metacarpal bones are collectively termed the **metacarpus.**

In the case of the horse (fig. 199, A), the only one of these bones which is well developed is metacarpal 3, corresponding with the bone extending from the wrist to the base of the middle finger. It is this bone (metacarpal 3) which forms the hard solid **cannon bone,** or shank-bone in the fore-foot (or hand) of the horse. This cannon bone is flanked by two very slender bones, which can be felt, one on each side. These are the **splint bones;** that on the inner side is metacarpal 2, and that on the outer side is metacarpal 4. These splint bones do not extend the whole length of the cannon bone. Metacarpal 1 and metacarpal 5 have entirely disappeared in the horse; the digits, I., II., IV., and V. are likewise absent.

But, as if to compensate for this suppression of four of the digits, the remaining digit (III.) is enormously developed. The arrangement, in fact, has gradually been evolved as an adaptation to rapid movement on a firm surface, where numerous small bones would be disadvantageous. The original stock from which horses have been derived consisted of small swamp-dwelling creatures, possessed of five digits to each foot.

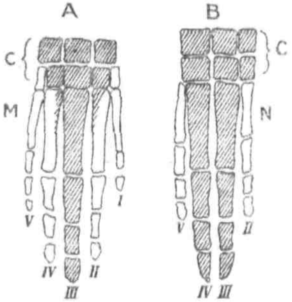


FIG. 199. — DIAGRAMMATIC REPRESENTATION OF THE FORE-FOOT OF—

A, an odd-toed or perissodactyle animal.
B, an even-toed or artiodactyle animal.
C, carpus or wrist ('knee ').
M, metacarpus.
I–V, digits.
The shaded parts indicate the bones that are *present* (A) in the horse, (B) in the ox and sheep.

FIG. 200.—SIDE VIEW OF BONES BELOW KNEE (CARPUS) OF HORSE.

A, cannon bone.
B, B, sesamoids.
C, pastern.
D, coronet.
E, coffin bone.
G, navicular (a sesamoid bone).

Double up the middle finger of the left hand, and notice the three joints—a basal joint next to metacarpal 3, a middle joint, and a terminal joint bearing the nail. The bones in these three joints are well seen in the single digit (fig. 200) of the horse. The uppermost one is called the *pastern*, the middle one is the *coronet* (so called because the *crown* of the hoof is around it), and the terminal one (buried in the hoof) is the *coffin*

bone. The *hoof* corresponds to the nail of a man's finger, but instead of being developed only on the back surface, it extends also round the front and sides. Behind the articulation of the coronet with the coffin bone, a 'floating' bone extends across from side to side. Veterinarians call this bone the 'navicular,' and it is the region of what is known as navicular disease. This bone must not, however, be confounded with the true navicular of anatomists, which is one of the bones of the hock (*see* p. 417).

The bones of the human leg have their counterparts in the hind-leg of the horse. The **femur**, or thigh-bone, extending from the hip to the knee, is hidden by the skin, but its movements can easily be seen as the horse moves. The femur has an almost spherical head, which fits into the acetabulum, thus forming a ball-and-socket joint. About one-third of the way down, on the outer side of the femur, is a roughened projection, in the form of a compressed ridge curving forwards, called the *third trochanter*, affording a surface of attachment for some of the powerful muscles that move the hind limbs. In cattle, sheep, and pigs, the femur has no third trochanter.

In the human leg there are two long bones extending from the knee to the ankle joint. Of these, the **tibia**, or shin-bone, is the stout strong bone on the inner side, and the **fibula** is the slender bone on the outer side. Both of these exist in the horse, but the fibula is extremely slender. In front of the human knee may be felt a 'floating' or sesamoid bone, the **patella**, or knee-cap, which also exists in the horse, at the region termed the *stifle joint*. The patella is attached by three strong ligaments to the tibia.

The bones in the human ankle are represented by the *hock* in the horse. The anatomical name for this region is the **tarsus**, and the bones composing it are called **tarsal bones.** In man, however, the tarsal bones, as well as the metatarsals and the digits of the foot, are laid flat on the ground, while in the horse they approach the perpendicular position. Suppose the 'near' hind-leg of a horse to be looked at from the front, then fig. 201

shows the names and positions of the bones that make up the hock.

On the outside of the hock the bones are seen to be two deep, the *calcaneum*, *os calcis*, or heel-bone, projecting upwards and backwards, and below it being the *cuboid*. On the inner side of the hock the bones are three deep: the top row is occupied by the *astragalus*, which has a beautiful pulley-like surface for articulation with the lower end of the shin-bone, or tibia; the middle row is occupied by the true *navicular* (called scaphoid, cuneiform magnum, etc., by veterinarians); and the lower row comprises the *internal cuneiform* and the *external cuneiform*, most of the last-named bone being behind.

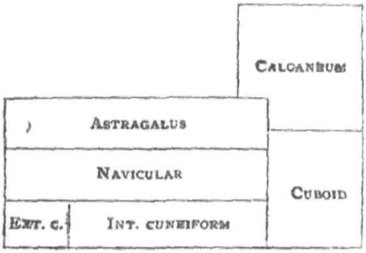


FIG. 201.—DIAGRAMMATIC VIEW SHOWING THE POSITIONS OF THE BONES IN THE TARSUS, OR 'HOCK,' OF THE HORSE.

The bones of the horse's hind-foot are similar in name and position to those of the fore-foot, and may be compared with those of the human foot in the same way as the horse's fore-foot was compared with the human hand. In man, the instep and toes of the foot correspond with the palm and fingers of the hand. The bones of the instep, being *beyond* the tarsals, are, however, called **metatarsals,** so that the cannon bone of the horse's hind-foot corresponds with metatarsal 3, the inner splint-bone is metatarsal 2, and the outer splint-bone is metatarsal 4. The metatarsal bones are collectively termed the **metatarsus.**

It is now possible to show the correspondence between the fore-limb and hind-limb of the horse:—

Fore Limb.	Hind Limb
Shoulder-girdle, or pectoral arch (scapula)	Hip-girdle or pelvic arch (innominate bone).
Humerus	Femur
{ Radius	Tibia }
{ Ulna	Fibula }
Carpals ('knee')	Tarsals ('hock')
Metacarpals (cannon bone and splints)	Metatarsals (cannon bone and splints)
Digital region ('foot') (Pastern, coronet, and coffin bones)	Digital region ('foot') (Pastern, coronet, and coffin bones)

At the back of the articulation of the cannon bone with the pastern, there are, in each limb of the horse, a couple of 'floating' *sesamoid* bones (fig. 200, B, B). Externally they are covered with a horny growth, the *ergot*, overlaid by a long tuft of hair, the *fetlock* (*i.e.*, 'footlock'). Fetlocks are peculiar to the horse, and vary in length and coarseness with the breed.

The Hoof of the Horse.—The coffin bone, the navicular, and the lower end of the coronet, form 'the articulation of the foot' (fig. 202). Four ligaments bind this articulation together. In addition, the *extensor tendon* passes down in front, and the *flexor tendon* behind. Outside these structures are two *fibro-cartilages*, one on each side, united behind and below by the *plantar cushion*. Outside, again, and fitting on the foregoing like a sock on a foot, is the *keratogenous* (*i.e.*, horn-producing) membrane, which secretes externally the epidermal material known as horn, of which the hoof is composed. The entire region is richly supplied with blood-vessels and nerves. The hoof is seen to become continuous with the ordinary skin at a circular line extending round the middle of the coronet; below, both in front and at the sides, is a semicircular protuberance, the *coronary cushion*. That part of the keratogenous membrane which is spread over the anterior face of the coffin bone is called the laminal or leafy tissue, because of the laminæ or parallel leaves seen on its surface; inflammation of this structure is called *laminitis*.

The hoof fits closely on the **keratogenous membrane**, of which, indeed, it is the product. Its general shape is that of a cylinder cut across obliquely. Prolonged maceration causes it to separate into three parts—the wall, the sole, and the frog.

The **wall**, or **crust**, is that part which remains visible when the hoof rests upon the ground. The middle

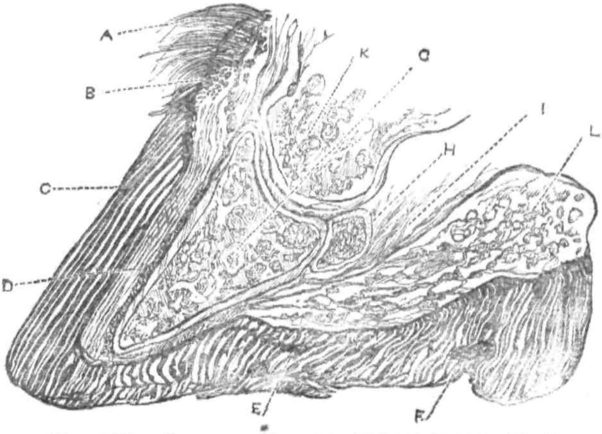


FIG. 202.—VERTICAL SECTION THROUGH MIDDLE OF HORSE'S HOOF.

A, skin of coronet.
B, fibres of coronary frog band.
C, fibres of wall.
D, horny lamina.
E, fibres of sole.
F, fibres of frog.
G, section of coffin bone.
H, section of navicular (a sesamoid bone).
I, section of flexor tendon.
K, section of coronet bone.
L, section of fatty frog.

anterior part is the **toe** (*outside* and *inside*); the lateral regions are the **quarters**; the angles of inflection at its hinder extremities are the **heels**; from thence, passing along the inner border of the sole, are the **bars**, which form outwardly the external faces of the *frog*. The **sole** has a large external curved border, and a much shorter internal border taking the form of a deep V-shaped notch, widest behind. This latter corresponds with the

bars, at the meeting of which the *point of the frog* is fixed. The **frog** is a pyramidal mass of horn lodged between the two re-entering portions of the wall. A *median lacuna* divides the inferior face of the frog into two divergent branches, the round, flexible, elastic, free ends of which are the *glomes*. The inclination of the wall of the hoof is from 50° to 56°, not 45°, as is often supposed. The flexibility of the hoof is promoted by a fluid secreted by the keratogenous membrane At the junction of the wall and sole is the *white line;* it is soft and flexible, and so prevents the breaking of the sole

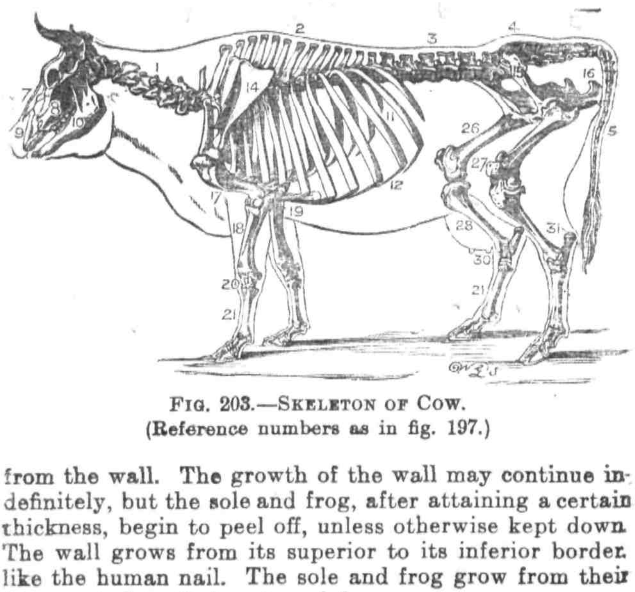


FIG. 203.—SKELETON OF COW.
(Reference numbers as in fig. 197.)

from the wall. The growth of the wall may continue indefinitely, but the sole and frog, after attaining a certain thickness, begin to peel off, unless otherwise kept down. The wall grows from its superior to its inferior border, like the human nail. The sole and frog grow from their deep-seated to their external face.

The skeleton of the ox (fig. 203) differs from that of the horse, in that the ribs are longer, wider, and flatter (notice a piece of 'ribs of beef' in a butcher's shop). The sternum is flat, not keel-like. The scapula is much broader at the top. The premaxillary bones do no

carry teeth, so that the ox has no incisors in its upper jaw, their place being taken by a hard pad, against which the incisors and canines of the lower jaw bite. In the skull the frontal bone is greatly developed; it is this bone that is pierced between the eyes by the pole-axe when a beast is slaughtered. The upper part of the frontal bone, in the region of the poll, is so thick that it is occupied by sinuses, or cavities, and it forms laterally the conical bony cores which, in horned cattle, support the horns.

The **horns** are made up of a bony core ensheathed by a strong horny epidermal case, the material composing which is secreted by a deep-lying membrane similar to the keratogenous membrane of the hoof. The bony core becomes hollow by the extension into it of the sinuses of the frontal bone; hence such horned ruminants (oxen, sheep, goats, antelopes) are classed as Cavicornia (hollow-horned). The horny sheath persists throughout life, growing with the bony core. The horny covering grows like any other part of the epidermis, or surface skin, its cells being secreted by that portion of the skin which is spread over the osseous cores of the frontal bones, completely enveloping the latter. This skin is richly supplied with blood-vessels.

The rings on the horn increase with age, the first appearing at two or three years; as age advances they get obliterated from various causes. In the bull the horns are short, thick, and powerful; in the ox, large long, and strong; in the cow, long and slender. In **polled** cattle, such as the Red Poll, the Aberdeen-Angus, and the Galloway, the bony outgrowths of the frontal bone have disappeared.

In the fore-foot of the ox the cannon bone consists of metacarpals 3 and 4 equally developed, but joined together along their inner faces. The digits of these metacarpals are fully developed, and are not joined to each other. As each carries its own separate hoof, the 'cloven hoof' is thus formed, which has been evolved with reference to walking and climbing on irregular surfaces. The hind-foot is similarly constructed.

in the middle and tapering at the ends. Such muscles, under suitable conditions, 'contract,' by which is meant that they become shorter and thicker, so that their two ends are brought nearer to each other. As one of these ends (the *origin*) is usually relatively fixed, the result is that whatever is attached to the other end (the *insertion*) is compelled to move. In this way the movements of the limbs are brought about. The rough surfaces, or ends, with which some bones are provided (*e.g.*, the third trochanter, p. 416), serve to facilitate the attachment of muscles, or of the fibrous cords or **tendons**, in which the latter often terminate.

METABOLISM.—When dealing with the functions of plants we saw (p. 140) that within the plant-body chemical changes, collectively known as metabolism, are constantly going on. It is, indeed, characteristic of living matter, as contrasted with non-living, that there should be a constant change of substance, although the outward form remains much the same, apart from modifications due to growth. As represented in the diagram known as the **metabolic staircase**, (p. 142) we have, on the one hand, processes of **up-building** (anabolism), by which food is converted into living matter (protoplasm), and, on the other hand, processes of **down-breaking** (katabolism), by which this living matter is resolved into simpler and simpler substances, until waste products are reached.

Much the same sort of thing takes place in an animal, but while in a green plant the food consists of carbon dioxide, water, and simple mineral substances, **an animal requires complex food** of organic nature, and all animals, in the long run, are dependent upon green plants for their supply of such food. An animal cannot, like a green plant, use the energy of sunlight to manufacture simple non-nitrogenous organic compounds from water and carbon dioxide. It follows that in sketching a metabolic staircase for animals the anabolic side must be represented as *shorter* than the katabolic side, since the food is already on a higher level than the waste products.

Metabolism is necessary in an animal for the same

reason as in a plant—*i.e.*, katabolism breaks down complex compounds into simpler ones with conversion of potential or stored energy into the kinetic or actual energy required to bring about movement, etc., while anabolism repairs the waste that thus takes place, and also renders growth possible. Katabolism is essentially a process of oxidation, and the free oxygen necessary to bring this about is taken in during **breathing** or **respiration,** an essential function in plants and animals alike.

Digestive Organs.—The digestive organs of the horse are concerned with taking in the food and digesting part of it—*i.e.*, converting it into solutions which are absorbed into the blood and carried to those parts of the body where repairs and growth are necessary. In this case the food consists of vegetable matter, together with the water that is drunk.

The digestive organs consist of a long tube, the **alimentary canal** or **gut,** which traverses the entire length of the body, and of certain **glands** connected with it. The successive regions of the canal are—mouth, pharynx, gullet, stomach, small intestine, large intestine (cæcum, colon, rectum) (fig. 205), and these will now be separately considered, while at the same time the course of the food through the body will be traced.

Commencing at the mouth, the food is crushed between the molar teeth, the muscles of the tongue and cheeks continually guiding it to where it can be chewed. Meanwhile the **salivary glands,** that open into the mouth, pour out a fluid called *saliva*, which moistens the food, and every now and again a bolus is moulded and passed to the back of the mouth, behind a fleshy curtain called the *soft palate* into a dilatation known as the **pharynx,** with which the nasal cavities are also connected. From the pharynx a distensible tube—the **gullet** or **œsophagus**—extends through the thorax, at the hinder end of which it pierces the diaphragm and enters the abdomen. Here the gut suddenly enlarges to form the **stomach,** a large bag, which in some animals occupies a considerable part of the cavity of the abdomen. The exit from the stomach is by a narrow

opening, called the *pylorus*, into the **small intestine**, a narrow, thin-walled tube, many times the length of the animal to which it belongs. Hence it is doubled up in an intricate fashion, in order that it may be accommodated within the restricted space contained in the abdominal cavity. Nor is it merely doubled upon itself many times—it is also slung up and kept in position.

Take a pocket-handkerchief and double it lengthwise, keeping the two edges uppermost. Within the

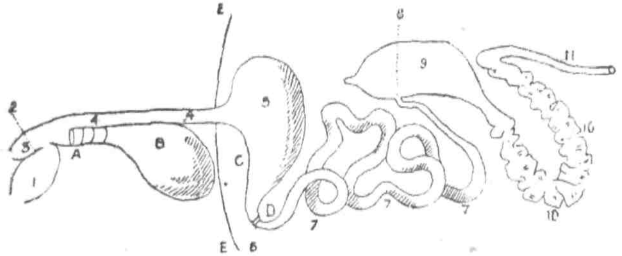


FIG. 205.—DIAGRAMMATIC REPRESENTATION OF THE ALIMENTARY CANAL (the intestinal parts proportionately much shortened).

1, mouth.	7, small intestine.
2, soft palate.	8, ileo-cæcal valve.
3, pharynx.	9, cæcum.
4, œsophagus or gullet.	10, colon.
5, stomach.	11, rectum.
6, pylorus.	

A, trachea.	D, region of pancreas.
B, position of lungs.	E E, position of diaphragm.
C, region of liver.	

fold, at the bottom, place a length of indiarubber tubing, so that it reposes between the two adjoining faces of the handkerchief. Now gather together, or pucker up, the free margins of the handkerchief that are in contact above, and, as a result, the indiarubber tubing will be coiled or doubled on itself. It is in a somewhat similar way that the long intestinal tube is packed and slung in the abdominal cavity. The place of the handkerchief is taken by a delicate transparent sheet of *connective tissue*, called the

mesentery, which is doubled on itself, so as to form a loop in which the intestinal tube reposes, whilst, between the two faces of the mesentery, which adhere together, delicate tubes or vessels pass to and from the intestine. The transparent filmy material—here and there laden with fat—which is often spread out upon a dish of pig's fry, gives a good idea of the nature of the mesentery. It should be added that the mesentery is continuous with a moist membrane, the **peritoneum,** that lines the abdominal cavity.

Traced onwards, the small intestine comes to an abrupt termination by opening suddenly into a much wider tube, called the **large intestine,** and consisting of three regions: firstly, the *cæcum*, or blind gut; next, the *colon;* and, finally, the *rectum*, which opens externally by the vent or *anus*.

Of the food which a mammal eats, part is digested—that is, converted into a soluble form fitted for absorption into the blood. The remainder, which escapes digestion, passes through the canal or tube which has been described, and is finally ejected from the body as dung. The course taken by such an undigested particle is, therefore, mouth, pharynx, gullet, stomach, small intestine, cæcum, colon, rectum.

The Ruminant Stomach.—It is popularly said that oxen and sheep have 'four stomachs.' It is more correct to say that, in these animals, the stomach comprises four compartments (fig. 206), all communicating with each other. The names of these compartments, in the order in which the food traverses them, are:—

1. The rumen or paunch (the 'tripe' of butchers is chiefly this).
2. The reticulum or honeycomb stomach.
3. The omasum, psalterium, or manyplies.
4. The abomasum, reed, or rennet stomach.

The capacity of the stomach in cattle is enormous, amounting to from fifty to sixty gallons, and filling the greater part of the abdominal cavity. The paunch alone is nine-tenths of the entire volume of the stomach, the remaining three divisions constituting a mere chain on the front left side of the paunch. In sheep and

goats, though absolutely smaller, the paunch is relatively as large as in the ox. The fourth division, or **abomasum,** is the only part of the ruminant stomach, the internal lining membrane of which secretes gastric juice. It is called the **rennet stomach,** because it is the fourth compartment of the calf's stomach, which is salted and preserved, in the form of 'vells,' to furnish natural rennet for use in cheesemaking. The secretion of the **gastric** or **peptic glands** (p. 429) supplies the rennet.

Ruminants can stow away, in the rumen or paunch, a huge quantity of vegetable food. This, at a suitable

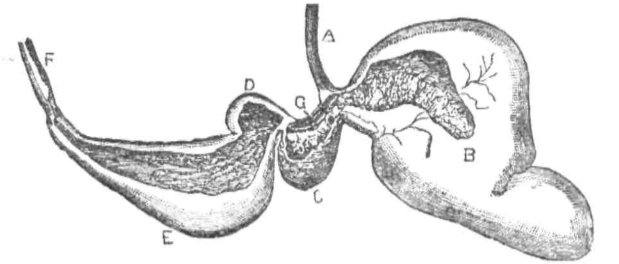


FIG. 206.—RUMINANT STOMACH (sheep).

A, gullet or œsophagus.
B, rumen or paunch.
C, reticulum or honeycomb.
D, omasum or liber.
E, abomasum or rennet stomach (the true digestive chamber).
F, small intestine.
G, gutter made by a fold of the lining membrane of C.

time, is regurgitated into the mouth, where it is mixed with the juice of the salivary glands, and slowly reduced to a fine condition between the teeth—this is called 'chewing the cud,' or **rumination.** Passing again down the gullet, the masticated food is this time directed along a gutter (fig. 206, G), through the third division, which acts as a strainer, and so into the fourth division of the stomach—the reed, rennet stomach, or abomasum. The glands imbedded in the lining of this compartment of the stomach pour out abundant gastric juice (p. 429) upon the food, which is at the same time

kept in continual motion by the peristaltic contractions (p. 430) of the wall of the organ. Through a narrow aperture, the pylorus, the material leaves the ruminant stomach, and pursues its course along the intestines, as in horses and pigs. The peculiar digestive organs of ruminants no doubt gradually came into existence as a means of protection, in a region where powerful carnivorous animals abounded. They enabled food to be rapidly swallowed, after which some place of security was sought, where the processes of chewing and digestion could be carried out at leisure. Existing wild ruminants—*e.g.*, antelopes—still benefit by this arrangement.

The Digestive Juices.—Connected with the alimentary canal are certain structures, called **glands,** which possess the power of manufacturing, out of the blood which flows through them, special juices, which they pour out in the form of **secretions.** Opening into the mouth are the **salivary glands,** already referred to (p. 425), and innumerable minute tubular **gastric** or **peptic glands** are imbedded in the lining of the stomach (abomasum in ruminants). They secrete the **gastric juice.** In the abdominal cavity are two very important glands, the *liver*, which secretes the *bile*, and the *pancreas* (or sweetbread), which secretes the *pancreatic juice*. Besides this, there are vast numbers of microscopic tubular **intestinal glands** in the lining of the small intestine. Their secretion is known as **intestinal juice.**

The **liver** is the largest gland in the body, and is packed, as it were, between the diaphragm and the stomach (fig. 205, c). By turning back its lobes there may be exposed an olive-green pear-shaped body, called the **gall-bladder,** connected with a tube that runs from the liver to the beginning of the small intestine, into which it opens. This tube is the *bile duct*, and along it flows the **bile,** a golden-coloured liquid, which the liver prepares from the blood, and which is poured in amongst the mass of food-material undergoing digestion in the small intestine. When there is not much food in the small intestine the process of digestion is less active, there is a diminished demand for bile, and the fluid is

then temporarily stored up in the gall-bladder. The horse is exceptional in that its liver has no gall-bladder.

The **pancreas**, or sweetbread, is a pale-coloured gland, which is distributed in a patchy fashion upon that portion of the mesentery which adjoins the stomach and (fig. 205, D) the U-shaped first part (duodenum) of the small intestine. The juice which it secretes is poured by means of a narrow tube, the *pancreatic duct*, into the small intestine, in the same way as the bile duct pours in bile.

It is now apparent that, in its passage through the alimentary canal, the food is subjected to the action of the saliva, the gastric juice, the pancreatic juice, the bile, and the intestinal juice, the joint effect of all of which is—in the case of a healthy animal—to dissolve such parts of the food as can be used for repairing waste and effecting growth. But an important question here arises. **Why does food travel along the alimentary canal?** How, again, can a horse or an ox pass its food along when, as in grazing, its head is lower than its stomach?

If a rabbit, or a rat, or any other mammal, is killed, laid on its back, and its abdomen opened *immediately after* death, the intestines are seen to be in continual *writhing* movement. During life, this wave-like motion is incessantly in progress throughout the entire length of the gut from the gullet onwards. A kind of gripping contraction takes place, travels onwards, and is at once followed by another, the result being that the food is propelled in the desired direction, and, in the stomach, undergoes a motion like that of churning. This movement in the gut is called **peristaltic contraction**, and it is the work of the muscular fibres which form the middle coat of the wall of the canal. The motion is involuntary—that is, it is not under the control of the will, and goes on unceasingly.

Classes of Food-stuffs.—In order to understand what changes food undergoes in the alimentary canal, it is necessary to learn something more (*see* pp. 137-8) of the general composition of the food-stuffs upon which animals subsist. These foods are made up of (1) nitro-

genous compounds, (2) fats, (3) carbohydrates, and (4) minerals and water.

The **nitrogenous compounds** (*proteins* or *albuminoids*, *amides*) contain the elements carbon, hydrogen, oxygen, and *nitrogen* (and, in some cases, sulphur and phosphorus). Examples are afforded by *albumin*, or white of egg; *gluten*, which remains as a sticky material in the mouth when new wheat is chewed; and the *casein* of milk, which is separated in the process of cheese-making, but is left in the skim-milk from which cream has been removed. Other compounds of the same character are *myosin*, which is the chief constituent of muscle (lean meat); *fibrin*, which occurs in clotted blood; *chondrin*, obtained by boiling cartilage (gristle); and *gelatin*, contained in connective tissue and in bones. The amides, such as *asparagin* and *tyrosin*, exist in immature vegetable products, as grass and roots (turnip, mangel). **Amides** may be regarded as intermediate between the nitrates which occur in the soil and the completely formed albuminoids which exist in plants. They are of less food-value than albuminoids. In unripe mangel a part of the non-albuminoid nitrogen actually exists in the form of nitrates.

Fats are substances rich in carbon, which is united with hydrogen and oxygen, the hydrogen being present in greater quantity than would be necessary to form water with all the oxygen. Hence, when a fat is oxidized or burnt, not only the carbon, but the surplus of hydrogen, is available for combining with oxygen from the outside. Oily seeds are specially rich in fat; Brazil nuts contain 67 per cent., palm nuts 47 per cent., poppy seeds 45, coconuts 36, linseed 34, cotton seed 24, and sunflower seed 22 per cent.

All vegetable foods, indeed, contain a greater or less proportion of fat or oil—oatmeal 10 per cent., maize 4, peas 2, barley 1·9, and wheat 1·6 per cent.

Carbohydrates, like the fats, are compounds of carbon, hydrogen, and oxygen only, but they contain no more hydrogen than is sufficient to form water with the oxygen present. Hence, when a carbohydrate is burnt, there is only its carbon available for oxidation.

Starch, sugar, cellulose, dextrin, gum, and pectin are examples of carbohydrates, and it is such compounds as these which form the largest part of vegetable food-stuffs. Maize, rye, and wheat contain between 65 and 70 per cent. of digestible carbohydrates; barley has 64 per cent., oats 57 per cent., peas 54 per cent., bran of wheat 51 per cent., potatoes 15 per cent., and parsnips 8 per cent.

The albuminoids, fats, and carbohydrates, which enter into the food of animals, are capable of being built up, so far as is known, only by the activity of living bodies, usually of plants. This is not the case with the mineral food-stuffs, of which water and common salt are the most familiar examples.

Of the classes of food-stuffs that have been enumerated, the proteins stand apart in the important characteristic that they alone contain nitrogen. Consequently, it is only these compounds that can supply the nitrogenous requirements such as the building up of flesh, etc., in the animal body. Hence, the proteins are termed *flesh-formers*, though they are also capable of placing carbon and hydrogen at the disposal of the animal body. So far as is known, the nitrogen in the inferior nitrogenous compounds—the amides—is not available for the production of muscle, but their carbon and hydrogen are utilized in the body.

For purposes of nutrition, fats and carbohydrates may be considered together. By their oxidation, heat is produced, and they are also competent to add to the store of fat in the animal body. They are, of course, necessarily incapable of building up nitrogenous tissues. They play an important part, however, in, as it were, shielding the nitrogenous matters from waste, because, in the absence of carbonaceous compounds, a demand for carbon and hydrogen would be made upon the nitrogenous substances.

Digestion.—Having acquired some knowledge of the general composition of food-stuffs, it is desirable now to enquire how such materials as hay fed to a bullock, or turnips and oil-cake fed to a sheep, are converted into beef or mutton. With such exceptions as sugar,

most of the solid constituents of the foods of animals are practically insoluble. By the process of digestion, however, these ingredients are brought into a form in which they can be absorbed by or taken into the blood. The chief agents in this process are **ferments**, complex proteins, of which minute quantities are contained in the digestive juices, bile excepted. As we have already seen when dealing with plants (p. 138), ferments are of great physiological importance, because they are able to bring about a very large amount of chemical change without being appreciably used up themselves.

The **saliva** which is poured into the mouth not only lubricates the food, thus softening it and rendering it easy to swallow, but also exerts a chemical action. It contains a very small quantity of a ferment known as **ptyalin,** that converts starch into malt-sugar and grape-sugar, which are readily soluble, and in the dissolved state can easily diffuse through a moist membrane. Ferments which act on starch in this way are said to be *amylolytic—i.e.*, starch dissolving.

Gastric juice is slightly acid, owing to the presence of a small amount (·2 per cent.) of free hydrochloric acid, which apparently acts as a germicide, destroying deleterious bacteria, etc., that happen to be swallowed with the food. This secretion contains two ferments: (1) **rennin,** which curdles milk; and (2) **pepsin,** which converts the comparatively insoluble proteins into soluble diffusible proteins called *peptones*. Rennet owes its peculiar properties to the presence of rennin (*see* p. 428). Because of its action on proteins pepsin is known as a *proteolytic—i.e.*, protein-dissolving ferment. Gastric juice has no effect upon starches or fats. But it helps to break up fatty tissue in that it dissolves the connective tissue which binds the fat vesicles together.

The **bile,** owing to its strongly alkaline character, plays an important part in *emulsifying* the fats—that is, in reducing them to a very fine condition, in which their particles are capable of being suspended in the body of a liquid. New milk is a good example of an emulsion, but, after the cream has been allowed to rise, it is hardly

possible, by any means, to again mix up the fatty particles with the liquid as thoroughly as before. So, when oil is poured on water in a bottle, it requires violent shaking to thoroughly mix the two—that is, to make an emulsion. The addition of a little carbonate of soda or similar alkaline substance renders this easy.

The **pancreatic juice** carries on the work begun by other digestive juices—saliva, gastric juice, bile. It is an alkaline fluid, containing three ferments: (1) *amylopsin*, which is amylolytic; (2) *trypsin*, which is proteolytic; and (3) *steapsin*, a fat-splitting ferment.

The **amylopsin** continues the work begun by the saliva of converting starch into sugar; the **trypsin**, like gastric juice, turns ordinary proteins into peptones; and the **steapsin** splits fats into the glycerine and fatty acids of which they are composed. At the same time the alkaline constituents of the pancreatic juice assist the bile in emulsifying the fats.

It need only be said of the **intestinal juice** that its action is somewhat similar to that of pancreatic juice. only very much feebler.

The net result of the chemical digestion described is to reduce a large part of the starch, fat, and proteins of the food into soluble substances that are absorbed into the blood, as will be subsequently explained (*see* p. 447).

It also appears that a part of the cellulose which makes up so much of the food of horse, ox, sheep, and goat, is converted into a soluble form within the alimentary canal. This, however, is not the work of the digestive juices, but is due to the ferment action of certain bacteria.

CIRCULATORY ORGANS.—It is clear that some arrangements are necessary to secure the distribution of digested food throughout the body, to carry waste products to the organs by which they are removed from the system, and also to maintain a uniform temperature. These duties are discharged by the circulatory organs, a set of tubes and other spaces containing the fluids known as blood and lymph, that serve as media of exchange, and are respectively contained in the blood

system and the lymph system, which are best considered separately.

Blood System.—A drop of fresh blood, obtained by pricking a finger-tip (after tightly winding a piece of string round the base of the end-joint) should be examined under a high power of the microscope (fig. 207). It will be seen to consist of a liquid (*plasma*) and of innumerable very minute *corpuscles*. These are of two kinds, red and white. The far more numerous **red corpuscles** are circular biconcave bodies, devoid of a nucleus (as in all mammals), and of a pale reddish-yellow colour, owing to the presence of a complex substance, *hæmoglobin*, resembling in some ways the green pigment (chlorophyll) of plants. When seen in bulk these corpuscles are red, and to them the characteristic colour of blood is due. They are of great importance in connection with respiration (*see* p. 443), and may be regarded as oxygen-carriers.

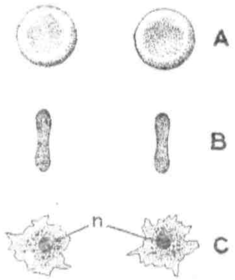


FIG. 207.—BLOOD CORPUSCLES. Highly magnified.
A, red corpuscles, seen flatwise; their thin centres are darkly shaded.
B, ditto, seen edgeways.
C, white corpuscles.
n, nucleus.

The **white** or **colourless corpuscles** (*leucocytes*) are larger and much less numerous than the red ones, and if treated with very dilute acetic acid are seen to contain a *nucleus*. When kept at the temperature of the body they exhibit a constant change of shape, and crawl about from place to place. They are, in fact, wandering cells, which perform a variety of functions. One important use of the colourless corpuscles of the blood (and lymph) is to serve as a kind of territorial army, engulfing and digesting disease bacteria that have entered the system.

It is a matter of common knowledge that blood, when exposed to the air, **clots** or **coagulates**, and this is of great practical importance, as otherwise an animal

would be liable to bleed to death as the result of even a slight cut or abrasion. The stages in coagulation are easily observed if a small quantity of freshly-drawn blood is placed in a beaker. First of all the blood becomes viscid, then it sets into a jelly, and, lastly, a rather firm red mass or **clot** is formed, which floats in a pale yellowish liquid known as **serum.** Examination of a minute fragment of the clot under the microscope will show that it is made up of corpuscles held together by exceedingly delicate interlacing fibres. The latter are composed of **fibrin,** a kind of protein, which does not exist as such in uncoagulated blood. What has taken place can be represented thus:—

UNCOAGULATED BLOOD

PLASMA — CORPUSCLES

FIBRIN

SERUM — CLOT

COAGULATED BLOOD

The formation of fibrin is due to the action of a substance known as *fibrin ferment*, which is derived from the white corpuscles.

The blood moves or circulates through the body in a closed set of tubes, the organs of circulation of the blood, which comprise (1) the *heart*, (2) *arteries*, (3) *veins*, and (4) *capillaries*.

The heart, which may be regarded as a central force-pump, is a hollow muscle, formed of two independent halves, right and left. Each half is divided into a thin-walled anterior compartment, the *auricle*, and a thick-walled posterior compartment, the *ventricle*. The whole organ is enveloped in a delicate membrane, the *pericardium*, forming a kind of double bag, with *pericardial fluid* between its two layers, and is lined internally by a

similar kind of membrane, the *endocardium*, flaps of which project inwards to form *valves*. Such valves exist at the orifice between the auricle and ventricle on each side, and also at the orifice leading out of each ventricle. The valves are so arranged as to permit the blood to flow from auricle to ventricle, and from ventricle outwards, but to prevent its passing in the opposite direction. In a state of healthy life, the blood in the left side of the heart is of a bright scarlet colour (*arterial* blood); that in the right side is of a dark purple hue (*venous* blood).

The vessels, or tubes, which carry blood *from* the heart are called **arteries**; those which convey blood *to* the heart are **veins**. The arteries spring from the ventricles, the veins discharge into the auricles. As an artery is traced away from the heart it is found to branch continually, the branches themselves breaking up in a similar way. The subdivision is continued until extremely narrow thin-walled tubes, the **capillaries**, at length result, and these permeate every part of the body, except the epidermis and its appendages (hair, wool, horn, etc.), and the cartilages.

Traced onward, the capillaries are found to give origin to the smaller veins, which become confluent into larger and larger veins, through which the blood returns to the heart.

Without entering at any length into the details of the circulatory organs, the student can acquire a knowledge of the chief facts by following the course of the blood from the heart back to the place of starting. The names of the chief vessels and tubes through which the blood flows can be mentioned incidentally.

Starting, then (fig. 208), with a particle in the scarlet blood of the left ventricle (1), it is driven by the contraction (beating) of the heart through the open *semilunar* valves into a strong elastic artery (2) called the **aorta.** This curves round to the left, and while it sends a branch (3) towards the head, the main trunk extends backward (4) beneath the vertebral column, and eventually divides into two *iliac* arteries (beneath the *ilia*, p. 412), one of which supplies the right hind-leg, and the

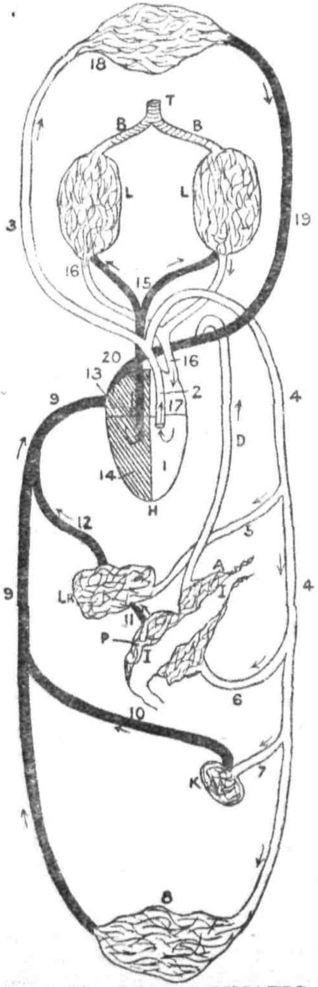


FIG. 208.—DIAGRAMMATIC REPRESENTATION OF THE CIRCULATORY SYSTEM IN A MAMMAL.

[The animal is supposed to be opened along the under or ventral side, and to be laid upon its back, so that the *left* of the animal is at the observer's right. The arrows indicate the direction of flow. The vessels along which *arterial* blood travels are unshaded (chyle flows through D); those which convey *venous* blood are represented by the full black colour. Notice that all the arteries *except* the pulmonary artery (15) carry arterial blood, and all the veins *except* the pulmonary veins (16) venous blood. In other words, whilst in the *systemic* circulation the arteries convey arterial blood and the veins venous blood, in the *pulmonary* circulation this state of things is reversed.]

H, heart (17, 13, auricles; 1, 14 ventricles.
L, L, lungs.
T, trachea, or windpipe.
B, B, bronchi.
K, kidney.
I, I, intestinal canal.
LR, liver.
A, lacteals.
D, thoracic duct.
P, blood-vessels carrying blood, and absorbed peptones, sugar, etc., from small intestine to portal vein (11).
1, left ventricle.
2, aorta.
3, artery supplying head and fore-limbs.
4, dorsal aorta.
5, hepatic artery supplying liver.
6, artery supplying intestines.
7, renal artery supplying kidney.
8, blood capillaries.
9, posterior vena cava.
10, renal vein.
11, portal vein.
12, hepatic vein.
13, right auricle.
14, right ventricle.
15, pulmonary arteries.
16, pulmonary veins.
17, left auricle.
18, blood capillaries.
19, vein from fore part of body.
20, anterior vena cava.

other the left. In due course the particle finds itself in a capillary (8), either in the pelvic region or in the limb. Hurried along in the current of the blood, it travels through the smaller veins, and ultimately reaches a great vein (9), the **posterior vena cava,** which extends beneath the vertebral column alongside the aorta. This vein passes forward, pierces the diaphragm—as does the aorta in passing backward—and throws the particle into (13), the right auricle of the heart. The contraction of the auricle drives the particle past the open *tricuspid valves* into (14) the right ventricle, the contraction of which propels it through the right *semilunar* valves into (15) the **pulmonary artery,** through the narrowing branches of which it reaches at length one of the blood capillaries in the air-cells of (L) the lungs (fig. 209). Thence it travels through the smaller veins of the lungs, and ultimately passes into (16) one of the **pulmonary veins,** which enter (17) the left auricle of the heart, whence the particle is driven past the open *mitral* valves into (1) the left ventricle, and so regains the point from which it started.

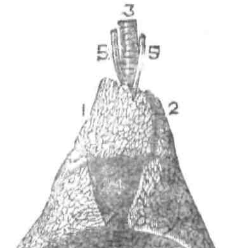


FIG. 209.—LUNGS OF SHEEP, seen from below.
1, right lung.
2, left lung.
3, trachea or windpipe.
4, heart.
5, carotid arteries, right and left.
6, vena cava posterior.

The contraction of the heart is *rhythmic*, or regular. First the auricles contract together, next the ventricles, and then there is a pause, after which the contractions are repeated. It is the the volume of blood suddenly thrown into the aorta by the ventricular contraction, and distending the walls of that elastic vessel, which produces the pulse. The number of pulsations corresponds, therefore, with the beating of the heart. Arteries are, as a rule, deep-seated, but the pulse can be felt at a few

places where an artery of some size passes along the surface of a superficial bone; in horses, on the border of the lower jaw, or inside the elbow; in cattle, under the tail, or on the middle of the first rib. As the pulse takes time to travel along the arteries, it is felt later in, say, the foot, than at the temple. The normal pulse of full-grown animals is, in the horse, about 36 per minute; in the ox, 55; in the sheep and pig, 75. In young animals it is more rapid, and when an animal is feverish the pulse is more frequent.

As the united sectional area of the arteries is much greater than that of the aorta, which supplies them, the pulse dwindles, and in the veins it has disappeared altogether. Indeed, so little is the effect of the ventricular contraction felt in the veins that they are provided with valves, arranged in such a way as to flap idly against the walls, while the blood is flowing, as it should, towards the heart, but to float across and bar the path should the blood attempt to flow in the reverse direction. By pressing the lower end of the *jugular* vein, which extends along the groove on either side of the neck of a horse, it is possible to 'fill the jugular'; for the moment, the blood is prevented from flowing on towards the heart, and the knotted appearances show the positions of the valves. We can understand from the above *why* the blood flows from a cut artery in jets or spurts, and from a cut vein in a steady but slower fashion. And it is worth remembering that bleeding from an artery can be arrested by pressure on the side *nearer* to the heart, while the opposite is true in the case of a vein.

It is now possible to answer two important questions. How does the dark (**venous**) blood in the right side of the heart differ from the scarlet (**arterial**) blood in the left side? What is the cause of this difference?

From what has been already stated, it is obvious that the change from dark blood to scarlet blood takes place during the passage from the right ventricle to the left auricle—that is, while the blood is passing through the capillaries of the lungs—this is called the *pulmonary* circulation. On the other hand, the blood is changed

from scarlet to dark purple during its course from the left ventricle to the right auricle—that is, in the capillaries of parts of the system other than the lungs—this is called the *systemic* circulation. The chief difference between the scarlet blood and the dark blood is that the former contains more oxygen and less carbon dioxide than the latter. If a *vein* is opened on the surface of the body, blood that is dark purple in colour flows from it. But it immediately becomes scarlet because, exposed to the air, it absorbs oxygen.

The scarlet blood that leaves the left ventricle is purer than the dark blood on the other side of the heart. In its passage through the capillaries of the system, however, the blood performs certain work. It carries material where it is required, and in this way it builds up or repairs the tissues, which it also supplies with oxygen. But it does more than this, for in all parts of the body waste is going on, and the products of such waste are swept away in the blood, to be carried to organs by which they are **excreted**, or removed from the system.

It is important to realize that the arteries and veins, especially the former, possess comparatively thick walls, through which diffusion cannot take place. The size or calibre of these vessels can be enlarged or diminished, owing to decreased or increased contraction of a muscular layer in their walls, and the supply of blood to a particular part can therefore be adjusted. Such adjustment is controlled by the nervous system.

The actual exchange of material between the blood and the living substance of the body takes place in the capillaries, by diffusion through the excessively thin walls of these microscopic vessels. At the same time the maintenance of an equable and constant temperature in all parts of the body is rendered possible.

Lymph System.—Everyone must have noticed the clear fluid that collects underneath a blister on the hand or foot. This is a local accumulation of **lymph,** a fluid that occupies certain large spaces in the body, such as the abdominal cavity, the pericardial cavity, and the pleural cavities, and also fills up the minute irregular

crevices in the various tissues. Microscopic examination shows that lymph consists of white or colourless corpuscles (*see* p. 435) floating in liquid plasma.

Connected with the lymph-spaces are a number of delicate **lymphatic vessels,** resembling small veins in structure, and ultimately opening into a slender tube, the **thoracic duct,** lying just below the backbone in the front part of the abdomen and in the thorax, and communicating with the great veins on the left-hand side at the base of the neck (fig. 208, D). At this point lymph is constantly flowing into the blood. The lymphatic vessels of the intestine have received the special name of **lacteals** (L. *lac*, *lactis*, milk), because after a meal containing fat they are seen to be filled with a milky-looking fluid. Here and there in the course of lymphatics rounded nodule-like bodies may be observed, a well-known example being the 'pope's eye' in a leg of mutton. These are the **lymphatic glands,** which may be regarded as manufactories of colourless corpuscles.

BREATHING OR RESPIRATORY ORGANS.—The **windpipe** (*trachea*) runs from the pharynx—below the gullet—along the ventral side of the neck into the thorax, where it divides into right and left bronchus, going to the corresponding **lung.**

Each of these organs is invested in a sort of double bag, the **pleura,** comparable to the pericardium (p. 436). The presence of a small quantity of lymph between the two layers of the pleuræ enables the lungs to glide over the inner surface of the thorax without friction as the respiratory movements take place. The disease known as *pleurisy* results from inflammation of the pleural membranes, and is associated with more or less friction and pain.

If we follow a bronchus into its lung we shall find that it divides in a branching manner into smaller and smaller tubes, the smallest and most delicate of these being called **bronchial tubes,** inflammation of which causes *bronchitis*. It may be noticed in passing that the termination 'itis' (met with in the names of many diseases) means 'inflammation,' a condition associated

with the local accumulation of colourless corpuscles for the purpose of attacking disease germs.

A bronchial tube ends in a group of minute *air-sacs*, the delicate walls of which are closely surrounded by a close network of capillary blood-vessels. Inflammation of the lungs or *pneumonia* is an inflammatory disease of the bronchial tubes and air-sacs, and is not infrequently associated with pleurisy, in which case the term *pleuro-pneumonia* is employed. The mischief is caused by the entry of certain bacteria.

The greater part of the spongy substance of the lungs is made up of the bronchial tubes, with their air-sacs. It is in the latter that the essential part of breathing or respiration takes place. This is the same in animals as in plants (p. 143), and consists of the taking in of pure oxygen, while at the same time the waste product, carbonic acid gas or carbon dioxide, is excreted or removed from the system. In the animal there is, so to speak, an exchange of material between the dark impure blood in the capillaries of the air-sacs and the air which these contain. Oxygen diffuses from the air into the blood, and carbon dioxide from the blood into the air. The latter also receives a good deal of water vapour, and a minute quantity of nitrogenous waste, while at the same time its temperature is raised. We consequently find that the air breathed out or exhaled differs considerably from the air breathed in or inhaled.

The blood going to the lungs is said to be **impure** —*i.e.*, it contains relatively little oxygen and a large amount of carbon dioxide. After a great deal of the latter has been got rid of in the lungs, and a fresh supply of oxygen taken up, it becomes **pure** blood, and flows into the left auricle of the heart. A word is necessary as to the marked difference in hue between these two kinds of blood. As already mentioned (p. 435) the red corpuscles owe their colour to the presence of the complex substance termed **hæmoglobin.** This is capable of taking up a certain amount of oxygen into loose chemical combination, and then becomes *oxy*hæmoglobin, which is bright scarlet. Hence the colour of pure or arterial

blood. Hæmoglobin of this kind, however, easily parts with its loosely combined oxygen, and then becomes *reduced* hæmoglobin, which is dark purple. The oxy-hæmoglobin of the pure blood which is pumped by the left ventricle of the heart to the capillaries of the body gives up its loosely combined oxygen to the tissues, and becomes *reduced* hæmoglobin. Hence the purple colour of impure or venous blood. We see, therefore, that the red corpuscles play the part of oxygen-carriers. They take up oxygen in the lungs and supply it to the tissues.

It is clearly necessary for the air in the lungs to be constantly renewed, and observation of a living animal show that **respiratory movements** are constantly taking place. During the breathing in or **inhalation** of air the volume of the thorax is increased, the lungs expand, and air flows into the larger air-tubes. The opposite takes place during the breathing out or **exhalation** of air. It is important to note that renewal of air in the bronchial tubes and air-sacs is effected by gaseous diffusion. The thorax is increased in volume from above downwards and from side to side by movements of the ribs and breast bone. By the contraction of muscular fibres (*intercostal muscles*) running obliquely between the ribs, these swing downwards and forwards. The increase of volume of the thorax from before backwards is caused by contraction of the diaphragm. This is really a flat muscle, with a fleshy margin ('skirting steak' of butchers) and fibrous or tendinous centre. There are also important muscular bands, the *pillars of the diaphragm*, running obliquely upwards and backwards from the dorsal part of this partition and becoming attached to the backbone. During a state of rest the margin of the diaphragm is *convex* towards the thorax. When air is breathed this margin becomes flattened by contraction of its muscular fibres and the pillars.

When air is breathed out the thorax is diminished in volume, largely owing to the return of the ribs and sternum to their former position, as the result of elasticity, while at the same time the diaphragm ceases to contract, and once more becomes convex towards the

thorax. The mechanical part of *respiration* or **breathing** is thus carried on, and the behaviour of the thorax may be likened to that of a pair of bellows working through the nozzle only.

From what has been said it is clear that animals constantly vitiate the surrounding air, and if they are shut up in low ill-ventilated houses, the consequences may be serious, and may even lead to suffocation should the air become too heavily charged with carbon dioxide.

During the passage of the blood from the left side to the right side of the heart the oxygen is largely occupied in oxidizing particles of carbonaceous matter in the blood itself, while oxidation is also constantly going on in the living substance of the body. Since oxidation is accompanied by heat, it will be understood **how the heat of the body is maintained.**

The term **excretion** is applied to the process of getting rid of the waste products formed by metabolism (p. 142), and organs which do this work are known as excretory organs. Since the **lungs** eliminate carbon dioxide and water from the system they obviously take part in excretion, and the **liver** is also an important excretory organ, for bile is really a waste product, though it aids the process of digestion before leaving the body. The remaining excretory organs are the skin and kidneys.

The skin, as is well known, is warm and moist, and water vapour is continually passing away from it. The warmth and moisture escape from the blood, the capillaries containing which exist just below the outer skin or epidermis, as is proved by the fact that even a shallow cut causes blood to ooze out. A small amount of saline matter passes away by the skin also. It is for the salt upon it that a calf or a cow will lick a man's hand with its rough tongue. As horses perspire freely, it is desirable to keep their skins clean and free from dust, so that the action of the skin may not be impeded. This object is effected in grooming.

The kidneys are the chief organs of *nitrogenous* excretion. They are situated in the dorsal part of the abdominal cavity, immediately below the backbone. To

protect them from violent shocks, each is imbedded in a soft semi-fluid cushion of fat, which in the carcase of an ox or a sheep is called 'suet.' Each kidney receives blood by a short *renal artery*, given off (fig. 208, 7) by the dorsal or abdominal aorta, and returns its blood by a *renal vein* into the *posterior vena cava*. The kidneys are made up of a great number of microscopic *urinary tubules*, intimately related to a complicated set of capillary vessels, from the blood circulating in which they remove the constituents of the *urine*. These include the nitrogenous waste products known as *urea* and *hippuric acid*, a large amount of water, and certain saline matters. It is because of the presence of nitrogenous waste that urine has a high manurial value, and that litter is spread in stables and byres to absorb this liquid, so that it may be used upon the land to promote the growth of crops.

The blood that leaves the kidney differs from the blood that enters it, in that it has lost all the ingredients which go to form the urine, and so far as nitrogenous waste is concerned it is the purest blood in the body. The excretion of urine by the kidneys is constantly going on, so that some means of getting rid of it are necessary. It continually trickles away from each kidney along a tube called the *ureter*. The two ureters open into a thin-walled, elastic, distensible bag, the *urinary bladder*, situated in the hinder part of the abdomen. From the bladder there issues a tube, the *urethra*, through which the contents of the bladder are periodically discharged.

The lungs, liver, skin, kidneys are thus seen to be **sources of loss to the blood.** Water is lost at each of them, whilst the lungs are specially distinguished by the loss of carbon dioxide, the skin by the loss of carbon dioxide and saline matters, and the kidneys by the loss of saline matters, urea, and hippuric acid.

With such waste always going on, it remains to inquire how the animal body is sustained, and by what means it is prevented, not only from wasting away, but is, on the contrary, caused to increase in size and

weight. To answer this inquiry it is necessary to return to the food in the alimentary canal.

The Absorption of Digested Materials.—It has been seen (p. 434) that the effect of the digestive juices is to break up all food-stuffs into three main portions—(1) the *dissolved* nitrogenous matters and sugar, (2) the *emulsified* fats, and (3) an *indigestible* residue. The last-named part, consisting largely of coarse fibre, travels through the intestinal canal, and, mixed with some of the intestinal secretions, is passed away in the form of excrement, which, in the case of horses and pigs and stall-fed cattle, usually finds its way to the dung-heap, whence it is returned to the soil.

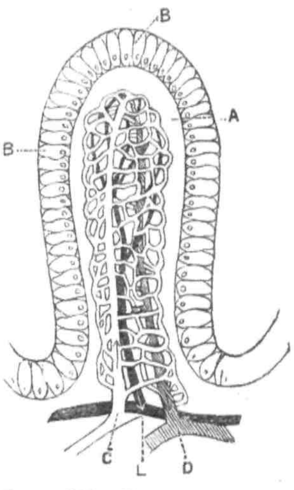


FIG. 210.—DIAGRAM OF A VILLUS OF THE SMALL INTESTINE.

A, body of the villus.
B, external covering of epithelium cells.
C, the small artery entering the villus, and breaking up into capillaries, which re-unite to form—
D, the small vein which leaves the villus;
L, the lacteal radicle which occupies the middle of the villus (solid black).

The dissolved matters and the emulsified fats are, on the other hand, taken up by the blood, and can thus be transported to all parts of the body. The *absorption* of digested materials by the blood is effected chiefly by the *villi* of the small intestine. Each villus is a minute club-shaped structure, projecting inwards from the internal lining membrane of the intestine. It is covered (fig. 210) by a layer of delicate cells surrounding a fine network of blood capillaries, originating in a minute artery which enters the villus, and converging upon a small veinlet which leaves it. Within this network is a

branching *lacteal radicle*, opening into a *lacteal vessel* (p. 442), which passes away from the villus.

Myriads of such villi line the internal surface of the small intestine. Their blood-vessels derive their blood-supply from the aorta, whilst all the veinlets which emerge from the villi become confluent, and pour their blood ultimately into a vessel called the **portal vein,** which passes into the liver (fig. 208, 11). There, unlike the great majority of veins, the portal vein breaks up, and the blood it contains is submitted to the action of the cells of the liver. The liver also receives a supply of arterial blood through the **hepatic artery,** which derives its blood from the aorta (fig. 208, 5). Without stopping to inquire into the minute structure and functions of the liver, it may be stated that this gland is drained of its blood by the **hepatic veins** (fig. 208, 12), which open into the *posterior vena cava*, this latter passing directly into the right auricle of the heart. Hence the blood that travels through the villi of the intestine passes, by way of the liver, into the heart.

The blood that leaves the intestinal villi is, however, different from that which enters them. Most of the dissolved products of digestion ooze through the delicate covering of the cells which envelop the villus much as a thimble covers the end of the finger, and the solution further diffuses through the extremely thin walls of the blood capillaries within the villus. Consequently the blood that flows from the villi of the intestinal walls carries with it the dissolved peptones and sugar, salts and soaps, that are derived from the food, together with most of the water taken in at the mouth.

But what becomes of the minute particles of emulsified fat that exist in the small intestine? These particles are split by ferment action into fatty acids and glycerine, which are taken up by the cells (fig. 210, B), covering the villus, and find their way, not into the blood capillaries, but into the **lacteal radicle** which the blood capillaries surround. Here they are recombined into globules of fat. The lacteal vessels which emerge from the villi become confluent, and ultimately pour

their milky-looking contents, called *chyle*, into the posterior end of the *thoracic duct* (fig. 208, D), ultimately reaching the right auricle of the heart (p. 442.)

Though the villi of the small intestine are the most active seats of absorption of digested materials, some amount of absorption of dissolved matters is begun through the blood capillaries in the walls of the stomach. Absorption is also continued, to a greater or less extent, throughout the intestinal tube. The rapidity with which absorption is capable of being effected is well illustrated in the instant alleviation of thirst which follows upon the taking of water into the stomach, whence it promptly passes into the blood capillaries.

It appears, therefore, that, though they travel along different routes, the dissolved peptones and sugar and salts, on the one hand, and the emulsified fats, on the other, find their way from the intestinal canal to the right side of the heart. From there, as has been seen, the blood is driven to the lungs to be oxygenated, thence to the left side of the heart, and from there to all parts of the body save the lungs. Not much is known of the exact processes whereby the blood, out of the materials it derives from the alimentary canal, enables the work of reparation or construction in all parts of the body—for example, the building up of bone in one place, the formation of muscular fibre in another, and the storage of fat in a third. We know, however, that repair and growth depend on the constructive activity of the living substance (protoplasm) of the body, and the materials for this work are the products of digestion.

But the student should now be in a position to grasp the fact that all parts of the animal body have at one time or another passed through, and formed part of, *the blood*, and, further, that the blood is the medium through which such materials as hay and corn and roots are manufactured into such products as beef and mutton, milk and wool.

The reader is cautioned against supposing that the *lacteal* vessels, whereby the finely divided fats are carried from the intestine into the blood, have any special connection with the secretion of milk at the mammary

glands. Both the chyle and the milk are emulsions of fat, but the former, as has been seen, is mixed with the blood in the right side of the heart, and has no direct relations with the milk-secreting organs.

Gains and Losses of the Blood.—To sum up with regard to the blood. It has been seen that the blood gains material (peptones, carbohydrates, fats, salts, water) from the food in the alimentary canal; that it gains material (oxygen) from the air in the lungs; that it gains material (the products of activity and waste) from the tissues generally; and that it gains material (lymph) from the lymphatics. On the other hand, the blood loses material (carbon dioxide and water) at the lungs; it loses material (urea, hippuric acid, water, saline substances) at the kidneys); it loses material (water, saline substances) at the skin; and it loses material (used for constructive purposes) in the tissues generally. The constitution of the blood is described on p. 435.

NERVOUS SYSTEM.—The various organs of the body are under the control of nerves, and it is through the nervous system that the movements of the body are co-ordinated, so that there shall be no conflict of purpose. The **brain,** with its posterior continuation—the **spinal cord**—constitutes the central part of the nervous system. The brain and spinal cord make up what is known as the *cerebro-spinal nervous axis*, the whole of which is securely lodged and efficiently protected in the bony chamber formed by the skull and the vertebræ. Processes or outgrowths, given off in pairs from the axis, form the cerebral and spinal **nerves.** Some of the former are nerves of special sense, as the olfactory nerve (associated with the sense of smell), the optic nerve (associated with sight), and the auditory nerve (associated with hearing). A number of pairs of very important nerves arise from a region called the *medulla oblongata*, at the junction of the brain and spinal cord. One of these, the *pneumogastric* nerve, or *vagus*, distributes its fibres to the heart, the lungs, and the stomach.

All muscular contraction takes place in obedience to nervous influence. This is equally the case with the

voluntary movements of the muscles of the limbs (as in running or walking), and with the involuntary movements of the intestinal canal (peristaltic contractions) and of the heart. The quantity of blood which shall flow to any part of the body is equally determined by the nervous system, inasmuch as the *vaso-motor* nerves control the calibre, or internal diameter, of the small arteries. Most important resultsarise from this circumstance.

The **sense organs** of touch, taste, smell, hearing, and sight are the means by which information about surroundings is obtained. A description of their structure and modes of action is outside the scope of this book.

Reproduction.—The horse and other kinds of farm stock, like all but the lowest members of the animal kingdom, propagate solely by means of **sexual reproduction,** the essentials of which are the same as elsewhere described for flowering plants (p. 164). It consists in the intimate fusion of a minute **egg-cell** or **ovum,** produced by the female, with a very much smaller **sperm** or **spermatozoon,** produced by the male (fig. 211). The sperm resembles a tadpole in shape, and is provided with a slender tail by the whip-like movements of which it is able to move about in the search for an ovum.

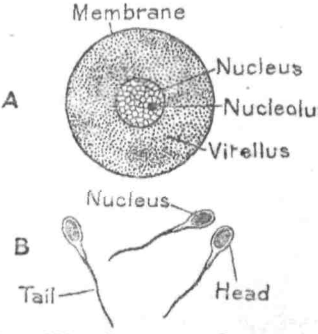


Fig. 211.—Ovum and Sperms. Highly magnified, B more than A. A, ovum ; network of chromatin in nucleus. B, sperms ; the dark spot in the head of each sperm is the nucleus.

After the ovum has been **fertilized** or **impregnated** by union with a sperm, it is able to grow into an **embryo.** In the case of the horse and all familiar mammals the embryo is known as a **fœtus,** and develops within the womb or uterus of the mother, to which it is attached by a complicated **after-birth** or **placenta.** This brings the blood system of the mother into close relation

with that of the fœtus, which is thus not only nourished, but enabled to get rid of its waste products and receive the oxygen necessary for breathing.

In a bird the ovum ('yolk' of the egg) is of large size, owing to the fact that it is crammed with nutriment to be used in building up the embryo. Before passing from the body of the mother a further supply of nutritive material ('white' of the egg) is added, and external to this a double membrane (shell membrane) and calcareous shell. Both the latter are pervious to air, for the developing embryo needs to breathe.

When hens' eggs are placed in 'water glass' the pores in the shell are blocked up and breathing prevented. Such eggs 'keep' because the development of their embryos is thus arrested.

CHAPTER XX.

COMPOSITION OF THE ANIMAL BODY

The chemical elements entering into the composition of the animal body are carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus, together with potassium, calcium, magnesium, and iron. To these may be added the elements chlorine and sodium, found in common salt, and a small percentage of fluorine in the teeth. The foregoing elements will be recognized as those occurring in plants, and, as animals feed on plants, this is not surprising.

There is, however, an important distinction in the details of nutrition of plants and animals. It has already been explained (pp. 142-3) that plants are capable, out of such crude materials as carbon dioxide, ammonia, water, and simple salts, of building up the complex organic compounds of which they are formed. Animals, on the other hand, are incapable of such work: they feed upon vegetable products, and ultimately reduce these to water, carbon dioxide, urea, etc., which have been

shown (p. 445) to be the waste products of the animal body, rejected by the blood at the lungs, the skin, and the kidneys. There is thus a kind of balance maintained between plants and animals—plants build up bodies of complex composition, animals reduce these to simple forms; plants consume carbon dioxide, animals evolve it.

In cutting up the body of an animal, the substances that are most obviously seen to enter into its structure are bone, flesh, and fat, to which may be added cartilage (or gristle) and connective tissue. It is desirable to inquire into the composition of these substances, for it is evident that the chemical elements they contain must be supplied to the animal in its food, otherwise the nutrition of the animal will be imperfect.

Bone.—A simple experiment serves to throw much light on the composition of bone. Take a bone, say the femur, out of a ham or out of a leg of mutton, though a much smaller bone from a rabbit will serve, and place it inside a drain-pipe, of width and length just sufficient to hold it. Plaster up the ends of the pipe with clay to prevent air from passing through, and then put it in the middle of a fire where it can be maintained at a red heat for some hours. On examining the bone when cool, it will be found to retain its original shape, but to have lost weight, and to have become so brittle as to be easily crushed to a powder. This powder consists almost entirely of phosphate of lime (calcium phosphate) and carbonate of lime (calcium carbonate), which contain between them the elements calcium, phosphorus, carbon, and oxygen, all of which, therefore, are necessary in the food.

Put a similar bone in a basin, and pour upon it dilute hydrochloric acid. After several days the bone will be found to have lost its rigidity, and much of its weight; it retains its original form, but may easily be bent. The nature of the soft flexible material which remains can be demonstrated by boiling it for a long time in water, when it will yield a large quantity of *gelatin*, which is a nitrogenous compound.

These experiments prove that bone consists of a

framework of animal matter, impregnated with salts of lime. By burning, the animal matter is removed; by treating with acid, the mineral matter is dissolved.

Connective tissue, like the animal basis of bone, yields gelatin as the result of prolonged boiling in water. As the water cools it forms a jelly. **Cartilage**, or gristle, similarly boiled, yields a material called *chondrin*, allied to gelatin. The composition of gelatin and of chondrin is shown in Table XXVII.

TABLE XXVII.—*Percentage Composition of* GELATIN *and* CHONDRIN.

	Gelatin.	Chondrin.
Carbon	50·76	47·73
Oxygen	23·21	31·04
Nitrogen	18·32	13·87
Hydrogen	7·15	6·76
Sulphur...	0·56	0·60
	100·00	100·00

Flesh owes its red appearance partly to the blood which it contains, and partly to the intrinsic colour of the ultimate muscular fibres of which it is composed. When lean meat is 'boiled to rags' the envelopes of connective tissue, which surround not only the entire muscles, but the individual fibres of which they are built up, are destroyed. The separate fibres can then be teased out with needles. The chief ingredient of muscular fibre is a nitrogenous substance called **myosin**, and this forms the greater part of the compound (*syntonin*) which can be obtained from lean meat by the action of dilute acids. Muscle also contains small but variable quantities of other proteins, as well as of fats, besides certain mineral matters, which include phosphorus and potash. Minute quantities of other substances may be obtained from muscle, the most interesting perhaps being **kreatin**, a nitrogenous crystalline material, which is probably the form in which most of

the nitrogenous waste of living muscle leaves the tissue before its conversion into urea (p. 446). Muscle contains about 75 per cent. of water, so that 4 lb. of lean beef or lean mutton will include about 3 lb. of water.

Fat.—The material called fat, as it is accumulated in the animal body, consists of oily or fatty substances stored up in minute cells, which are bound together by a framework of connective tissue. Expose a piece of suet to a gentle heat before the fire, and, as the melted fat trickles away, the collapsed framework of connective tissue is left behind. By pulling to pieces a lump of suet, the connective tissue is again brought under notice. The common fats of the animal body are *stearin*, *palmitin*, and *olein*. The first named, used in making candles, is most abundant in hard fats, such as mutton suet. Palmitin also occurs in quantity in palm oil, and olein in olive oil.

CHAPTER XXI.

FOODS AND FEEDING

In the **selection of food for farm animals** several distinct objects have to be kept in view. For all animals it is necessary, in the first place, that sufficient food be given to meet the daily wants of the body; in other words, to make good the losses that are always taking place through the lungs, the skin, and the kidneys. This may be called the **maintenance diet.** It is evident that such a diet must supply the animal with the elements entering into the composition of the materials which are lost in the way just referred to; though a sufficiency of oxygen is always obtainable from the air. Hence, even for the purpose of maintenance only, the food must include some proteins, because these alone contain nitrogen. Though an animal may have an unlimited quantity of carbohydrates or fats at its disposal, it will

cease to thrive unless it can also get proteins; eventually, indeed, it will die of nitrogen starvation.

The other objects to be kept in view in framing a diet must depend upon the animal itself, and upon what it is intended for. A horse, for example, has to do work; this leads to much oxidation and the consequent production of heat within the body, accompanied by the wearing or wasting of the muscular tissues. A milch cow parts daily with a large quantity of fluid containing nitrogenous, carbonaceous, and mineral matters. A stall-fed ox is neither doing work like the horse, nor is he yielding milk like the cow, but he is storing up fat in his system. A calf or a lamb is not performing external work, it is not yielding milk, and it is not storing up fat; but it is growing, which means that it is making bone and muscle and other tissues, whereby its body is increased in size and weight.

Not much thought is required to understand that the diet which would exactly meet the requirements of any one of these animals would not be the diet best suited to the needs of each of the three remaining animals. The working horse, the milking cow, the fatting ox, and the growing lamb all make special demands which must, in each case, be specially met. Hence it is to the interest and the profit of the farmer to learn what kinds of food are best suited to particular cases, and then to endeavour to supply these in the cheapest possible form.

The idea of cheapness involves, however, a consideration not only of the actual cost of the material, if it has to be bought, but also of the value of the manure which an animal yields whilst consuming such material. (*See* pp. 466-7).

Flavour is another condition that must not be overlooked. It cannot be measured by the balance, nor can it be expressed by numbers, but it is a most important factor in inducing animals to partake freely of their food, and the skilful feeder knows the value of making the diet of animals attractive and appetizing. Condimental foods are useful because of the relish they impart.

The student is already familiar with the fact (p. 430) that in food-stuffs are found three main classes of available material: (1) the nitrogenous (proteins or albuminoids); (2) the non-nitrogenous or carbonaceous

TABLE XXVIII.—*Percentage Composition of* ORDINARY FOODS.

Food.	Water.	Nitrogenous Substance.		Fat.	Soluble carbo-hydrates.	Fibre.	Ash.
		Albuminoids	Amides, &c.				
Cotton cake (decorticated)	8·2	43·2	1·8	13·5	20·8	5·5	7·0
" " (undecort.)	12·5	20·7	1·3	5·5	34·8	20·0	5·2
Linseed cake	11·7	26·9	1·1	11·4	33.2	9·0	6·7
Rape cake	10·4	28·1	4·6	9·8	29·1	10·3	7·7
Earthnut cake	11·5	45·1	1·9	8·3	23·1	5·2	4·9
Beans	14·3	22·6	2·8	1·5	48·5	7·1	3·2
Peas	14·0	20·0	2·5	1·6	53·7	5·4	2·8
Wheat	13·4	10·7	1·3	1·9	69 0	1·9	1·8
Rye	13·4	10·5	1·0	1·7	69·5	1·9	2·0
Oats	13·0	10·6	0·7	5·4	57·3	10·0	3·0
Barley	14·3	10·2	0·4	2·1	66·0	4·5	2·5
Maize	11·0	9·8	0·6	5·1	70·0	2·0	1·5
Malt sprouts	10·0	16·6	7·1	2·2	44·1	12·5	7·5
Wheat bran	13·2	12 1	2·0	3·7	56·0	7·2	5·8
Brewer's grains	76·2	4·9	0·2	1·7	10·7	5·1	1·2
" " (dried)	9·5	19·8	0·8	7·0	42·8	15·9	4·7
Rice meal	10·3	11·3	1·0	12·0	47·8	8·6	9·0
Oat straw	14·5	3·5	0·5	2·0	37·0	36·8	5·7
Barley straw	14·2	3·2	0·3	1·5	39·1	36·0	5·7
Wheat straw	13·6	3·3		1·3	39·4	37·1	5.3
Pea straw	13·6	9·0		1·6	33·7	35·5	6·6
Bean straw	18 4	8·1		1·1	31·0	36·0	5·4
Pasture grass	76 7	2·9	1·1	0·9	10·9	5·2	2·3
Clover (bloom beginning)	81·0	2·6	0·8	0·7	8·0	5·2	1·6
Clover hay (medium)	16·0	10·5	2·5	2·5	37·2	25·0	6·3
Meadow hay (best)	15·0	10·2	1·8	2·3	39·5	24·0	7·2
" " (medium)	15·0	8·0	1·2	2·2	42·0	25·4	6·2
" " (poor)	14·0	6·3	0 5	2·0	41·1	31·0	5·1
Grass silage (stack)	67·0	3·3	1·5	1·5	13·2	9·7	3·8
Clover silage (stack)	67·0	3·3	2·7	2·2	10·5	11·9	2·4
Maize silage	79·1	1·0	0·7	0·8	11·0	6·0	1·4
Potatoes	75·0	1·2	0·9	0·2	21·0	0·7	1·0
Cabbage	85 7	1·7	0·8	0·7	7·1	2·4	1·6
Carrots	87·0	0·7	0·5	0·2	9·3	1·3	1·0
Mangels (large)	89·0	0 4	0·8	0·1	7·7	1·0	1·0
" (small)	87·0	0·4	0·6	0·1	10·2	0·8	0·9
Swedes	89·3	0·7	0·7	0·2	7·2	1·1	0·8
Turnips	91·5	0·5	0·5	0·2	5·7	0·9	0·7

(carbohydrates and fats); (3) the mineral ingredients. Many of the common foods in use upon the farm are distinguished by containing much more of one of these classes of ingredients than is present in other foods, and may thus be spoken of as *nitrogenous* foods, *fatty* foods, *starchy* foods, or *watery* foods, as the case may be.

The percentage composition of ordinary foods is shown in Table XXVIII., compiled by R. Warington.

Note the high position occupied by **oilcakes**, both as **nitrogenous** and as **fatty** foods. Inasmuch as albu-

TABLE XXIX.—*Composition of average samples of* DECORTICATED COTTON-CAKE *and* UNDECORTICATED COTTON-CAKE *and of average samples of* LINSEED-CAKE *of different qualities.*

	Decorticated cotton-cake.	Undecorticated cotton-cake.	Linseed-cake.		
			Low quality.	Good quality.	Very good quality.
Moisture	10·64	13·30	11·99	12·32	11·87
Oil...	10·23	5·24	7·52	10·55	12·59
[1]Albuminous compounds	44·19	23·17	33·22	28·31	30·09
Mucilage, sugar, digestible fibre, &c.	23·42	32·27	33·86	34·47	32·37
Woody fibre (cellulose)	4·88	20·79	7·46	8·30	6·94
Mineral matter (ash) ...	6·64	5·23	5·95	6·05	6·14
	100·00	100·00	100·00	100·00	100·00
[1]Containing nitrogen	7·07	3·71	5·31	4·53	4·81

minoids and fat are the most concentrated of the constituents of animal food, it is evident that small quantities of oilcake may be made valuable adjuncts to less nutritious food. In other words, a little oilcake—particularly decorticated cotton-cake and linseed-cake—goes a long way.

Complete analyses are set forth in Table XXIX. of the kinds of oilcake most commonly used for feeding. Besides, however, affording a satisfactory result on analysis, oilcakes—as, indeed, other food-stuffs—should possess good *condition* (that is, soundness, freedom

from mould, freshness, and sweetness). In the absence of these qualities, the use of a feeding-stuff may be productive of ill results, not on account of anything that can be shown by the figures of an analysis, but solely from staleness, over-heating, bad keeping, etc.

Impure inferior linseed-cake often contains weed seeds (owing to imperfect screening), also sand, the sweepings of floors, etc.

The starchy grains of the **cereal crops stand first in** the percentage of **carbohydrates.** In the actual analyses set forth in Table XXX., the carbohydrates make up from one-half to two-thirds of the entire substance.

TABLE XXX.—*Composition of average samples of* WHEAT, BARLEY, OATS, *and* PEA-MEAL.

	Wheat.	Barley (grittled)	Oats (crushed).	Pea-meal.
Moisture	17·54	17·30	12·50	15·38
Oil	1·60	1·91	6·30	1·33
[1]Albuminous compounds ...	11·81	8·87	13·06	23·56
Starch, digestible fibre, &c. ...	65·37	65·10	57·17	54·43
Woody fibre (cellulose) ...	1·63	4·12	7·87	2·91
Mineral matter (ash)	2·05	2·70	3·10	2·39
	100·00	100·00	100·00	100·00
Containing nitrogen ...	1·89	1·42	2·09	3·77

In mineral or ash ingredients, rice-meal, made of the husks of rice, is notably rich, as are also rape-cake and malt sprouts.

As regards the constituents of the ash, oilcakes and bran are richest in phosphoric acid; straw and hay are poorest. Potash is abundant in malt sprouts, oilcakes, bran, bean straw, and roots, but is deficient in the cereal grains. Lime is largely contained in the ash of turnips, and in the hay and straw of leguminous crops, but it occurs only in small quantity in potatoes and in the cereal grains, maize and rice amongst the latter being specially poor in lime.

Succulent foods, containing high percentages of

water, are necessarily correspondingly poor in the valuable food ingredients. Note that the potato contains considerably less water than the turnip, mangel, carrot, etc. Whilst 100 lb. of potatoes would include 25 lb. of solid matter, 100 lb. of turnips would contain only 8 to 10 lb. of solids. There is more water in turnips than in milk (*see* Table XXVIII., p. 457).

In Table XXXI. below are given complete analyses of swede and mangel.

In turnips and swedes the leaf contains a higher percentage of dry substance than the root, and the dry substance of the leaf includes a much higher per-

TABLE XXXI.—*Composition of average samples of* SWEDE *and* MANGEL.

	Swede.	Mangel.
Water	89·23	87·80
[1]Albuminous compounds	·98	1·12
Sugar	5·54	6·41
Starch, digestible fibre, &c.	2·74	3·08
Woody fibre (cellulose)	·85	·78
Mineral matter (ash)	·66	·81
	100·00	100·00
[1]Containing nitrogen	·16	·18

centage of both nitrogen and total mineral matter than does that of the root. In turnips the proportion of leaf to root is much higher than in swedes. Moreover, whilst in turnips a very large amount of the matter grown is accumulated in the leaf and only serves as manure again, in swedes a comparatively small proportion of the produce is useless as food for stock.

Turnips, swedes, and mangels are essentially sugar crops. The *average* amount of dry matter may be put approximately at 8 per cent. in white turnips, 9 per cent. in yellow turnips, 11 per cent. in swedes, and 12·5 per cent. in mangel. Of the dry matter of white and yellow turnips nearly one-half, or more, may be sugar;

of that of swedes more than one-half; and of that of mangel nearly, or as much as, two-thirds may be sugar. One reason for keeping mangel is that the sugar in the root is only properly developed during the process of storing.

The foods poorest in water—that is, the driest, or most solid foods—are those rich in fat. For example, decorticated cotton-cake has only 8 per cent. of water, and linseed-cake about 12 per cent. Hays and straws, cereal grains, beans, and peas all contain between 14 and 16 per cent. of water.

Whilst concentrated foods are more especially called for in the case of horses and pigs, which possess com-

TABLE XXXII.—*Average composition of the* STRAW *of* WHEAT, BARLEY, *and* OATS.

	Wheat straw.	Barley straw.	Oat straw.
Moisture	14·3	14·2	14·3
[1]Albuminous compounds	3·0	3·5	4·0
Starch, sugar, digestible fibre, &c.... ...	38·0	38·0	38·1
Woody fibre (cellulose)	40·1	40·2	39·6
Mineral matter (ash)	4·6	4·1	4·0
	100·0	100 0	100·0
[1]Containing nitrogen	·48	·56	·64

paratively small stomachs, and through whose intestinal canals the food passes somewhat rapidly, in the case of cattle and sheep, on the other hand, fodders containing a considerable amount of indigestible fibre are not only useful but necessary. They impart bulk and solidity to the mass undergoing digestion, and they help to keep the paunch full, this division of the ruminant stomach never being entirely empty, even in the case of starving animals. A sheep is capable of digesting about twice as much as a horse of the total organic matter contained in the chaff of wheat straw. Straw, hay, and undecorticated cotton-cake are particularly rich in fibre.

The cereal straws are extensively cut up into chaff in order to be used as fodder, though they are sometimes fed to stock in the long condition. Their *average* composition is shown in Table XXXII., most of the soluble carbohydrates in each case being cellulose.

A comparison is afforded, in Table XXXIII., between the proportions of the ingredients found in three of the commonest bulky feeding-stuffs.

The figures given in the tables of this chapter are not to be accepted in too arbitrary a sense. Different samples of any kind of feeding-stuff, natural or artificial, may be expected to yield somewhat different results, when subjected to chemical analysis. The slight variations which may be detected in some of the percentages here recorded will serve to illustrate this fact.

TABLE XXXIII.—*Composition of average samples of* GRASS, MEADOW HAY, *and* CLOVER HAY.

	Grass.	Meadow hay.	Clover hay.
Moisture	73·67	17·90	18·60
[1]Albuminous compounds	2·15	7·25	12·50
Starch, sugar, digestible fibre, &c	15·02	46·13	36·33
Woody fibre (cellulose)	7·36	22·62	25·65
Mineral matter (ash)	1·80	6·10	6·92
	100·00	100·00	100·00
[1]Containing nitrogen ...	·42	1·35	2·01

The chemical composition of a food is only a partial guide to its feeding value. It is necessary also to take into consideration the extent to which each constituent of the food is digestible. For example, clover hay contains about 12 per cent. of nitrogenous matter, but not much more than half of this is digested in passing through the system of a bullock or of a sheep. On the other hand, the small proportion—about 2 per cent.—of fat in barley is practically all digested. The proportion of each ingredient digested depends upon the food itself, upon the nature of the other foods with which

it is accompanied, and also upon the kind of animal, whether horses, cattle, sheep, or pigs. The term **digestion co-efficient** is used to denote the proportion of each constituent digested for every 100 parts supplied in the food. Thus, a horse can digest about 60 per cent., or three-fifths, of the fat in maize, a cereal containing 5 per cent. of this ingredient. The digestive co-efficient in this case, therefore, is 60.

Young grass is much more digestible than old grass or hay. This explains the highly nourishing character of rich pastures in the early summer months, during which animals are continually grazing upon fresh young shoots of the herbage.

Closely associated with the digestion co-efficient is the idea involved in the term **albuminoid ratio.** All the organic ingredients of a food belong to one or other of two groups—the albuminoid, and the non-albuminoid. Of each of these a certain percentage is digestible, and the albuminoid ratio denotes the relation of the digestible albuminoids to the digestible non-albuminoids. Before this relation can be indicated by numerals, it is necessary to express all the digestible non-albuminoids in terms of one of them, and the one selected is starch. By multiplying by 2·3 the percentage of digestible *fat* in a food, the equivalent in digestible *starch* is obtained. Of the commoner foods none possess so high an albuminoid ratio as decorticated cotton-cake, in which it is 5 : 7, by which is meant that for every 5 parts by weight of digestible albuminoids there are 7 parts of digestible non-albuminoids. For purposes of comparison of different foods it is convenient always to express the digestible albuminoid as 1, in which case the ratio just given becomes 1 : 1·4. Cakes, pulses, and bran all have high albuminoid ratios; in the case of roots the albuminoid ratios are low; and, in the case of the cereal straws, very low.

For the information of the student, it may be useful to show **how an albuminoid ratio is calculated.** Take the analysis of *oats* in Table XXX. Here the percentage of fat is 6·3, which, multiplied by 2·3, gives 14·49. Add to this 57·17 for the carbohydrates, and the sum is 71·66.

Hence, the albuminoid ratio, in the case of oats, is 13·06 : 71·66, or 1 : 5½. Again, take the analysis (Table XXIX.) of *linseed cake*, of good quality. Here, 10·55 × 2·3 = 24·265, and 24·265 + 34·47 = 58·735. Hence, the albuminoid ratio is 28·31 : 58·735, or as nearly as possible 1 : 2. The ratios, as thus obtained, are only approximately correct, for it has been *assumed* that the organic constituents which enter into the calculation are entirely digestible, and that all the nitrogen is in the albuminoid form.

It is obvious, however, that, as the albuminoid ratio depends upon the digestion co-efficient, the albuminoid ratio of a food-stuff must vary according to the kind of animal to which the food is given. The subject is too intricate to be further pursued in an elementary work. It may be added, however, that some of those who have made a study of the principles of stock-feeding make use of the albuminoid ratio in order to devise mixtures or combinations of foods which shall yield the best result in the circumstances given.

For the practical stock-feeder the problem is how to turn to the **best commercial advantage** the food-stuffs he has already got on his farm—the hay, straw, roots, etc., which are produced in the ordinary routine of farming. His skill is exercised in purchasing such additional foods as can be most profitably associated for feeding purposes with the produce of the farm. In making his selection, he is bound to take into consideration the market prices of the various purchasable foods, and also to allow some weight to the residual manurial value of the mixtures he proposes to use.

The most valuable **ingredients of manure**—nitrogen, phosphoric acid, and potash—will obviously be more abundant in the case of fully-grown animals put up for fattening than in the case of animals still growing, or of milch cows. Table XXXIV. shows the *average* percentage of dry matter in certain cattle foods, and the quantities of that dry matter which may be classed as nitrogen and ash respectively. The last two columns show how much of the ash is phosphoric acid and how much is potash. In other words the 'dry matter' in

the first column includes the 'nitrogen' and 'mineral matter' in the second and third columns; whilst the

TABLE XXXIV.—*The Average Percentage of certain* CONSTITUENTS *in* CATTLE FOODS.

Food.	Dry matter.	Nitrogen.	Mineral matter (ash)	Phosphoric acid.	Potash.
	per cent.	per cent.	per cent.	per cent.	per cent.
Linseed	90·00	3·60	4·00	1·54	1·37
Linseed-cake	88·50	4·75	6·50	2·00	1·40
Decorticated cotton-cake	90 00	6·60	7·00	3·10	2 00
Palm-nut cake	91·00	2·50	3·60	1·20	0·50
Undecorticated cotton-cake	87·00	3·75	6·00	2·00	2·00
Coco-nut cake	90·00	3·40	6·00	1·40	2·00
Rape-cake	89·00	4·90	7·50	2·50	1·50
Peas	85·00	3·60	2·50	0·85	0·96
Beans	85·00	4·00	3·00	1·10	1·30
Lentils	88·00	4·20	4·00	0·75	0·70
Vetches (seed)	84·00	4·20	2·50	0·80	0·80
Maize	88·00	1·70	1·40	0·60	0·37
Wheat	85·00	1·80	1·70	0·85	0·53
Malt	94·00	1·70	2·50	0·80	0·50
Barley	84·00	1 65	2·20	0·75	0·55
Oats	86·00	2·00	2·80	0·60	0·50
Rice-meal	90 00	1·90	7·50	0·60	0·37
Malt culms	90·00	3 90	8·00	2·00	2·00
Fine pollard	86·00	2·45	5·50	2·90	1·46
Coarse pollard	86·00	2 50	6·40	3·50	1·50
Bran	86·00	2·50	6.50	3·60	1·45
Clover hay	83 00	2·40	7 00	0 57	1·50
Meadow hay	84·00	1·50	6·50	0·40	1·60
Pea straw	82·50	1 00	5·50	0·35	1·00
Oat straw	83·00	0·50	5 50	0·24	1·00
Wheat straw	84 00	0·45	5·00	0·24	0·80
Barley straw	85·00	0 40	4·50	0·18	1·00
Bean straw	82 50	0·90	5·00	0·30	1·00
Potatoes	25·00	0·25	1·00	0·15	0·55
Carrots	14 00	0·20	0·90	0·09	0·28
Parsnips	16·00	0·22	1·00	0·19	0 36
Swedes	11 00	0 25	0·60	0·06	0·22
Mangels	12·50	0 22	1·00	0·07	0·40
Yellow turnips	9·00	0·20	0·65	0·06	0 22
White turnips	8·00	0·18	0·68	0·05	0·30

TABLE XXXV.—*Showing the Composition, Manurial and Compensation Values of* FEEDING STUFFS (Revised in 1913 from Lawes and Gilbert's Tables, 1897, and Voelcker and Hall's Tables, 1902).

No.	Foods.	Valuation per Ton as Manure. A Nitrogen. Per cent. in food.	A Nitrogen. Value at 15s. per unit.	A Nitrogen. Half of Value to Manure.	B Phosphoric Acid. Per cent. in food.	B Phosphoric Acid. Value at 3s. per unit.	B Phosphoric Acid. Three-quarters of Value to Manure.	C Potash. Per cent. in food.	C Potash. Value at 4s. per unit.	C Potash. Three-quarters of Value to Manure.	Compensation Value for each ton of Food consumed. D. Food made into dung. (1) Before one crop has been removed or harvested.	D. Food made into dung. (2) After one crop has been removed or harvested.	D. Food consumed on land. (3) Before one crop has been removed or harvested.	D. Food consumed on land. (4) After one crop has been removed or harvested.	Foods.	No.
			s. d.	s. d.		s. d.	s. d.		s. d.	s. d.	s. d.	s. d.	s. d.	s. d.		
1	Decorticated cotton cake	6·90	103 6	51 9	3·10	9 4	7 0	2·00	8 0	6 0	64 9	32 4	85 6	32 4	Decorticated cotton cake	1
2	Undecorticated cotton cake (Egyptian)	3·54	53 2	26 7	2·00	6 0	4 6	2·00	8 0	6 0	37 1	18 6	47 9	18 6	Undecorticated cotton cake (Egyptian)	2
3	Undecorticated cotton cake (Bombay) ...	3·10	46 6	23 3	2·50	7 6	5 7	1·61	6 5	4 10	33 8	16 10	13 0	16 10	Undecorticated cotton cake (Bombay) ...	3
4	Linseed cake ...	4·75	71 4	35 8	2·00	6 0	4 6	1·40	5 7	4 2	44 4	22 2	58 10	22 2	Linseed cake ...	4
5	Linseed	3·60	54 0	27 0	1·54	4 7	3 5	1·37	5 6	4 2	34 7	17 3	45 4	17 3	Linseed	5
6	Soya-bean cake ...	6·85	102 8	51 4	1·30	3 11	2 11	2·20	8 10	6 7	60 10	30 5	81 6	30 5	Soya-bean cake ...	6
7	Palm-nut cake ...	2·50	37 6	18 9	1·20	3 7	2 8	0·50	2 0	1 6	22 11	11 5	30 6	11 5	Palm-nut cake ...	7

8	Coco-nut cake ...	3·40	51	0	25	6	1·40	4	2	3	1	2·00	8	0	6	0	34	7	17	3	44	9	17	3	Coco-nut cake ...	8
9	Earth-nut cake ...	7·62	114	4	57	2	2·00	6	0	4	6	1·50	6	0	4	6	66	2	33	1	83	1	33	1	Earth-nut cake ...	9
10	Rape cake... ...	4·90	73	6	36	9	2·50	7	6	5	8	1·50	6	0	4	6	46	11	23	5	61	8	23	5	Rape cake ...	10
11	Beans	4·00	60	0	30	0	1·10	3	4	2	6	1·30	5	2	3	10	36	4	18	2	48	4	18	2	Beans	11
12	Peas	3·60	54	0	27	0	0·85	2	7	1	11	0·96	3	10	2	10	31	9	15	10	42	6	15	10	Peas	12
13	Wheat	1·80	26	10	13	5	0·85	2	7	2	0	0·53	2	1	1	7	17	0	8	6	22	5	8	6	Wheat	13
14	Barley	1·65	24	10	12	5	0·75	2	3	1	8	0·55	2	2	1	7	15	8	7	10	20	8	7	10	Barley	14
15	Oats	2·00	30	0	15	0	0·60	1	10	1	5	0·50	2	0	1	6	17	11	9	0	23	11	9	0	Oats	15
16	Maize	1·70	25	6	12	9	0·60	1	9	1	4	0·37	1	6	1	1	15	2	7	7	20	4	7	7	Maize	16
17	Rice meal ...	1·90	28	8	14	4	0·60	1	9	1	4	0·37	1	6	1	1	16	9	8	4	22	6	8	4	Rice meal... ...	17
18	Locust beans ...	1·20	18	0	9	0	0·80	2	5	1	10	0·80	3	2	2	4	13	2	6	7	16	9	6	7	Locust beans ...	18
19	Malt	1·82	27	4	13	8	0·80	2	5	1	10	0·60	2	5	1	10	17	4	8	8	22	9	8	8	Malt	19
20	Malt culms ...	3·90	58	6	29	3	2·00	6	0	4	6	2·00	8	0	6	0	39	9	19	10	51	6	19	10	Malt culms ...	20
21	Bran	2·50	37	6	18	9	3·60	10	10	8	2	1·45	5	9	4	4	31	3	15	7	38	10	15	7	Bran	21
22	Brewers' grains (dried)	3·30	49	4	24	8	1·61	4	10	3	8	0·20	0	10	0	8	29	0	14	6	38	11	14	6	Brewers' grains (dried)	22
23	Brewers' grains (wet)	0·81	12	4	6	2	0·42	1	3	0	11	0·05	0	2	0	1	7	2	3	7	9	9	3	7	Brewers' grains (wet)	23
24	Clover hay ...	2·40	36	0	18	0	0·57	1	9	1	4	1·50	6	0	4	6	23	10	11	11	31	0	11	11	Clover hay ...	24
25	Meadow hay ...	1·50	22	6	11	3	0·40	1	2	0	11	1·60	6	5	4	8	16	10	8	5	21	4	8	5	Meadow hay ...	25
26	Wheat straw ...	0·45	6	8	3	4	0·24	0	9	0	7	0·80	3	2	2	4	6	8	3	1	7	7	3	1	Wheat straw ...	26
27	Barley straw ...	0·40	6	0	3	0	0·18	0	6	0	4	1·00	4	0	3	0	6	4	3	2	7	6	3	2	Barley straw ...	27
28	Oat straw	0·50	7	6	3	9	0·24	0	9	0	7	1·00	4	0	3	0	7	4	3	8	8	11	3	8	Oat straw	28
29	Mangels	0·22	3	4	1	8	0·07	0	3	0	2	0·40	1	7	1	2	3	0	1	6	3	8	1	6	Mangels	29
30	Swedes	0·25	3	10	1	11	0·06	0	2	0	1	0·22	0	11	0	8	2	8	1	4	3	7	1	4	Swedes	30
31	Turnips	0·18	2	8	1	4	0·05	0	2	0	1	0·30	1	2	0	11	2	4	1	2	2	10	1	2	Turnips	31

'mineral matter' in the third column includes the 'phosphoric acid' in the fourth column, and the 'potash' in the fifth.

The food-stuffs used on the farm fall naturally into three classes. These are (1) the succulent foods grown on the farm, such as pasture grass, clover, and root crops (including mangels, turnips, swedes, cabbage, kale, rape, kohl rabi, etc.); (2) dry foods grown upon the farm, such as grass and clover hay, straw, and grain of all kinds; (3) purchased foods, such as oilcakes, brewers' grains, malt culms, maize, etc. Of course it may happen, and sometimes does, that a farmer finds it convenient to purchase foods belonging to either or both of the first two classes, but this does not alter the fact that these foods are the direct produce of the farms of this country. Where live-stock are maintained upon a farm, part or all of which is under the plough, the usual practice is to feed the green crops to the stock, as also in winter and partly in summer the stored roots and the hay and straw, and to sell off the farm the grain (cereals and pulses) which has been grown thereon.

Table XXXV. gives the manurial and compensation values of the chief feeding stuffs.

CHAPTER XXII.

THE PRINCIPLES OF BREEDING

The art of breeding plants or animals is regulated by certain scientific principles, which are grasped without particular difficulty. A knowledge of principles alone, however, will not make a successful breeder, whose work requires in addition skill of eye and hand, sound judgment, and constant experience. But at the same time it is increasingly recognized that sound scientific knowledge will prevent mistakes, save time, and in every way promote the objects in view.

SPECIES AND VARIETIES.—Animals and plants include an enormous number of kinds or **species**, each of which may be said to 'breed true,' and includes a collection of individuals that are sufficiently alike to justify the conclusion that they have all descended from a common stock. Horse, ass, rabbit, hare, barn owl, perch, garden snail, large cabbage-white butterfly, common tapeworm, and liver fluke, will serve as common examples of animal species, while on the plant side we may take beech, daisy, charlock, dandelion, Scots pine, bracken fern, and American gooseberry mildew. It will have been noticed, in the preceding part of this book, that a particular kind or species of organism has a double scientific name—*e.g.*, the horse is termed *Equus caballus* and the daisy *Bellis perennis*. The second or *specific* name (*i.e.*, *caballus* or *perennis*), is that of the species, while the first name (*i.e.*, *Equus* or *Bellis*), is *generic*, applying to the **genus**, which usually includes a number of allied species. For example, the wild cat, tiger, and lion are different species of the genus *Felis*, and are respectively known as *Felis catus*, *Felis tigris*, and *Felis leo*. Similarly among grasses the genus *Poa* includes three common species, rough-stalked meadow grass (*Poa trivialis*), smooth-stalked meadow grass (*Poa pratensis*), and wood meadow grass (*Poa nemoralis*).

It was at one time generally believed that every species was created independently, and this carried with it the idea of a sharp distinction between different species. Such well-marked boundaries, however, are by no means universally present—*e.g.*, it has always been a difficult task to distinguish between the numerous species of willows and brambles. In other words, similar or 'allied' species may or may not be clearly defined.

Even in the days when the distinctness of species was generally accepted, it was universally acknowledged that certain species included two or more groups of individuals, each constituting a **race** or **variety**. A notable example is afforded by the field snail (*Helix hortensis*), of which about ninety varieties have been described, some 'self-coloured,'

and others with a number of dark bands in addition. The dog rose (*Rosa canina*) is another good instance, for it includes some twenty-nine recognizable varieties. It may be added that the term **sub-species** is often used to designate a subdivision of a species presenting more clearly marked characters than a variety

A considerable number of varieties of cultivated plants and domesticated animals have arisen under the artificial conditions imposed by man, these being commonly called 'breeds' in the case of animals. Berkshires, Tamworths, Large Blacks, and so forth, are distinct pig **breeds,** all apparently belonging to the wild boar species (*Sus scrofa*), while the innumerable **varieties** of the potato are all descended from the American potato plant (*Solanum tuberosum*).

Hybrids and Mongrels.—It will now be realized that the distinction between species and varieties is one of degree rather than of kind. In a large number of cases, however, though not in all, we find that different species will not breed together at all, or if they do the resulting **hybrids** are infertile when paired. Mules, for instance, are crosses between the horse (*Equus caballus*) and ass (*Equus asinus*), two related species, but there is no authentic case of mules producing offspring. The same is true for the zebroids or zebra-mules, obtained by Professor Cossar Ewart by crossing zebra and horse.

It is also nearly always the case that allied varieties or breeds can easily be crossed, while the **mongrels** thus produced are almost invariably fertile. The different races of domesticated pigeons afford a good illustration, while the new varieties of potato constantly being produced are obtained by crossing existing varieties.

Evolution and Origin of Species.—It is now almost universally believed that the innumerable existing species of plants and animals have descended from pre-existing species by a series of modifications, or, in other words, have arisen by a process of **evolution.** We can, indeed, actually trace the pedigrees of some forms with more or less accuracy, the best-known example being that of the horse (*see* p. 415). But while hardly any instructed person doubts the *fact* of evolution our

knowledge of the actual *method* of evolution is still incomplete, although some existing theories no doubt include much of the truth.

Darwinism.—This name is conveniently applied to the 'theory of natural selection,' independently conceived by Charles Darwin and Alfred Russel Wallace, whose views were simultaneously published on July 1st, 1858. Darwin's *Origin of Species*, which gives a detailed account of the theory, appeared the following year. The general nature of the argument is conveniently set forth in tabular form.

Proved facts.	Necessary consequences.
Rapid increase in numbers ... Limited space and supply of food Total numbers fairly stationary .	Struggle for existence.
Struggle for existence ... .. Variation	Survival of the fittest, or natural selection.
Natural selection ... ... Heredity	Modifications in structure and origin of new species.

All plants and animals naturally tend to increase with great rapidity, and this has been strikingly shown by rabbits in Australia, sparrows in North America, and Scotch thistles in parts of South America, all three being introduced forms. The limitations of space and food supply obviously render indefinite increase impossible, and the fact that the numbers of a particular species in a given area do not fluctuate, on the average, to a large extent, shows that checks to increase must exist. It follows that there is a **struggle for existence** on the part of the members of any species, partly against unfavourable weather, and the like, and partly with competing organisms for food and foothold. The fight for soil-food, light, and air between the crowded plants in a pasture or hedge is sufficiently obvious, and it is clear that the various insect-eating birds must enter into a keen competition for prey.

Admitting the struggle for existence, we have further to consider the facts of **variation.** The members of the same family or the same litter, or the seedlings sprouting from the seeds produced in the same fruit, are by no means precisely alike. They vary in all sorts of ways, and such variation is a primary law of life in all its forms. Some individuals are always fitter to carry on the struggle for existence than their fellows, and therefore have a better chance of living and producing offspring. Hence the doctrine of **survival of the fittest,** otherwise known as **natural selection.** The latter term was coined by Darwin to express the picking out or 'selection' of favourable variations by nature, just as by 'artificial selection,' through the agency of man, variations which serve his purpose are picked out for breeding purposes. Darwin, in fact, made a profound study of cultivated plants and domesticated animals, and everyone who desires to acquire an intimate knowledge of the art of breeding should read his great work, *Plants and Animals under Domestication.* Some of the most important facts which support the Darwinian theory are drawn from the results obtained by cultivators and breeders, and just as these are able to produce new varieties of plants and breeds of animals by artificial selection, so is 'nature' (a collective term for natural agents) supposed to be able to originate new varieties of plants and animals by natural selection. Such natural varieties are aptly termed 'species in the making,' because some of them are distinct enough to render it probable that they may ultimately become sufficiently fixed in character to deserve the name of species.

That natural selection actually takes place can hardly be doubted, and it is also undoubtedly the fact that the offspring of individuals which are thus selected may **inherit** the variations which have given an advantage in the struggle for existence. Hence the possibility of the formation of new varieties, and ultimately new species, by the intensification of structural modifications which have arisen by variation.

HEREDITY.—In the sexual reproduction of plants and

animals the structural and other characters of a variety or species are transmitted from one generation to another by means of the germ-cells, male and female, the former being called a sperm in animals and lower plants (part of the contents of the pollen-tube being equivalent in most seed-plants) and the latter an egg-cell or ovum (*see* p. 451). An animal or plant, except in the very lowest groups, consists of body or **soma** and the **germ-cells.** The latter alone constitute the link between successive generations, and we may therefore speak of 'germinal continuity.' From the point of view of heredity the most important part of a germ-cell would appear to be its nucleus, especially that part of it known as the **chromatin,** which stains deeply when treated with dye-stuffs, as may be seen by microscopic examination (fig. 211, A). Weismann supposes that a portion of this chromatin consists of a special substance, the **germ-plasm,** whence his expression 'continuity of the germ-plasm.' The actual existence of germ-plasm has not, however, been demonstrated with certainty, and we must for the present be content with knowing that germ-cells do undoubtedly represent the inheritance with which individuals start their existence.

Reversion, Atavism, or **Throw-back.**—It is important to remember that the germ-cells embody, as it were, a number of characters which have been handed down through many generations, and during the development of an individual there is a sort of competition between the excessively minute particles which are supposed to transmit these characters, a struggle for existence in miniature which may end in widely different ways, according to the influences acting upon the embryo. The average result is that an organism resembles its parents, or one of them, more closely than more remote ancestors. But it sometimes happens that characters which correspond to peculiarities in a grandparent, great-grandparent, or can be traced even further back, gain the upper hand. We then speak of throw-back, atavism, or reversion, and, remembering the continuity of germ-cells through successive generations, this is a perfectly intelligible phenomenon.

Prepotency and In-breeding.—It often happens that special characters possessed by an individual are transmitted with great persistency, though why this should be so can only be conjectured. Such an individual is said to be **prepotent**, and it appears to be the case that prepotency is favoured by prolonged in-breeding—*i.e.*, breeding between near relatives. This is so generally recognized that in-breeding is always resorted to when a race embodying new characters, or a new combination of characters, is sought to be established. The practice, of course, tends to emphasize undesirable as well as desirable features, and is commonly stated to lead in the end to reduction in size, liability to disease, and sterility. In spite of all this, in-breeding is one of the most powerful agents in the hands of cultivators and breeders.

Transmission of Acquired Characters.—This is a subject over which endless discussion has taken place, and, like germinal continuity, it is closely associated with the name of Professor Weismann. An 'acquired' character is one that makes its appearance in the body or soma of an individual, as the result of the activity of the individual with reference to its surroundings, or due to the direct influence of the latter. Good examples are afforded by bodily peculiarities associated with certain occupations, as the hardening of the hands due to constant use of the spade, or outward curving of the legs in the case of men who spend a large part of their time in the saddle. Weismann, and most men of science who have carefully studied the matter, believe that such characters are *not* transmitted to offspring, but many breeders think otherwise.

The question of acquired characters is of great practical importance, because such a character occurring in, say, a bull might very well be desirable from the breeder's standpoint, but, if Weismann's views are correct, it would be waste of time to try and establish it by artificial selection. The whole subject is one of extreme difficulty, on which the last word has not yet been said. The balance of evidence, so far as this is based on accurate observation, is decidedly against the transmission of acquired characters. But it is one thing

to define such characters on paper, and quite another to recognize them when they are actually present in given individuals, whether plants or animals.

Variation.—Although it is undoubtedly true that 'like tends to beget like,' it is equally true that the likeness is never complete, and that there are always differences between parents and offspring. In other words, organisms tend to **vary**, to a smaller or larger extent. These differences are believed to be due to variations that take place in the germ-cells—*i.e.*, to **germinal variation,** and they differ from acquired characters or modifications in that there is no doubt about their being inheritable.

It is convenient to use the term **fluctuations** for variations of small amount, and in constructing his theory of evolution, it was upon the existence of these that Darwin mainly relied. It is, however, extremely doubtful whether new varieties of plants and breeds of animals can be established by artificial selection of fluctuations, and the origin of species by natural selection of such small differences also presents a number of difficulties, of which this is not the place to give a detailed account.

Contrasting with fluctuations we find that **discontinuous variations, mutations,** or **sports,** arise from time to time, both in plants and animals. It is these which in all probability have furnished the chief material for natural selection, while their importance in artificial selection is unquestioned. One notable peculiarity about such variations is their marked prepotency. The 'wonder horse,' Linus I., with an 18 feet mane and a 21 feet tail, was a good example of a sport, while Shirley poppies and star primroses (*Primula stellata*) both arose by the sudden appearance of mutations. Sports in desirable directions, especially when occurring in males, obviously afford invaluable material for the exercise of the art of the breeder.

Mendelism.—Breeding by the selection of favourable variations is more likely than not to prove unsuccessful, for the simple reason that most obvious variations are only fluctuations, and as such unlikely to produce marked

improvement. It is only when the favourable variations happen to be prepotent mutations that progress will be made, and these occur in a very haphazard fashion, and are difficult to recognize as such unless they happen to be of a kind that appeals to the eye. For example, a mutation of disease-resisting kind might suddenly make its appearance, and this, though very real, could not be actually *seen*, and its existence would only be discovered by its prepotency as manifested in breeding. It is consequently a long-standing practice to resort to **cross-breeding** with the object of 'breaking the type,' in the hope that something valuable may turn up.

In the absence of definite laws upon which to proceed, the results of such cross-breeding used to be very much a matter of chance, but of late years much light has been thrown upon the subject by the exponents of what is known as Mendelism. Mendel was Abbot of Brünn (in Austria), who published a remarkable paper on plant-breeding in 1866, though its importance was not realized at the time, nor, in fact, until its re-discovery in 1900.

Mendel experimented on the cross-breeding of peas, and observed that the different varieties of these possessed certain characters of sharply-contrasting kind—*e.g.*, tallness and dwarfness. Such pairs of characters are now known as **Mendelian characters.** The results of crossing a tall with a dwarf pea are represented in the following **table**:—

VARIETIES CROSSED.	TALL × DWARF		
1st mongrel generation (F_1).	All Tall Bred together these gave		
2nd mongrel generation (inbred) (F_2).	25 % Tall (pure dominants)	50 % Tall (impure dominants)	25 % Dwarf (pure recessives)
3rd mongrel generation (inbred) (F_3).	Tall	25 % Tall (pure dom.) 50 % Tall (impure dom.) 25 % Dwarf (pure recess.)	Dwarf

Of the two opposed Mendelian characters present in the varieties originally crossed—*i.e.*, tallness and dwarfness—the former is possessed by all the members of the first generation of resulting mongrels (F_1), and hence is said to be **dominant,** while dwarfness is said to be **recessive.** When these mongrels are bred together, 25 per cent. of the offspring are said to be **pure dominants,** because they are tall, and breed true in this respect, while for a similar reason another 25 per cent. of the offspring, which are dwarf, are termed **pure recessives.** But the remaining 50 per cent. of the offspring are called **impure dominants,** because, though tall themselves, they have evidently not got rid of the dwarf element, for, when inbred, their offspring, like those of the first mongrel generation, may be divided into 25 per cent. pure dominants, 25 per cent. pure recessives, and 50 per cent. impure dominants, which, when once more inbred, give a similar result.

A very interesting case of Mendelian inheritance is afforded by Blue Andalusian fowls, of which it is impossible, as is well known to breeders, to establish a pure strain. They are obtained by crossing black and white Andalusian fowls, with the following results (F_1, F_2, and F_3 have the same meaning as in the last table):—

BLACK × WHITE

F_1			All Blue		
F_2	25°/₀ Black (pure dominants)		50°/₀ Blue (impure dominants)		25°/₀ White (pure recessives)
F_3	Black (pure dom.)	25°/₀ Black (pure dom.)	50°/₀ Blue (impure dom.)	25°/₀ White (pure recess.)	White (pure recess.)

It appears, then, that Blue Andalusians are impure dominants, but have a distinct colour of their own, instead of being black. They are, so to speak, permanent mongrels, the blue colour being transmitted to only half their offspring.

Purity of Germ-cells.—Mendel explained the remarkable results of which examples have just been given by

supposing that germ-cells, male and female, are 'pure' as regards any pair of Mendelian characters. In the case of the tall and dwarf peas, for instance, he supposed that a given germ-cell contained only the tall or the dwarf element, not both. Assuming this to be true, all the germ-cells of the original tall variety would embody the quality 'tall,' and all those of the dwarf variety the quality 'dwarf.' Further, the germ-cells of the mongrels (F_1), obtained by crossing these two varieties, would embody one or other quality. Supposing them to do so in equal proportion, then, if we take the case of—

Female Germ-cell.	*Male Germ-cell.*
2 Tall	2 Tall
2 Dwarf	2 Dwarf

a 'tall' female germ-cell has an equal chance of being fertilized by a 'tall' or a 'dwarf' male germ-cell, and similarly in the case of a 'dwarf' female germ-cell. This would give—

Female.		*Male.*
Tall	×	Tall.
Tall	×	Dwarf.
Dwarf	×	Tall.
Dwarf	×	Dwarf.

Of the four embryos, subsequently growing into adults, thus brought into existence, one would result from union of germ-cells both embodying the dominant character (tallness), two from the union of unlike germ-cells, and one from the union of germ-cells embodying the recessive character (dwarfness). The proportion would be

1 : 2 : 1

equalling

25 % 50 % 25 %

exactly as in the second mongrel generation (F_2) in the two tables already given.

Practical Results. — By working with Mendelian characters valuable results have been obtained with

plants, and it may be ultimately possible to attain similar success with animals, though this matter is at present only in the experimental stage. It will here be interesting to note a few Mendelian characters in addition to the two already given.

	Dominant.	Recessive.
Edible pea	Round seeds	Wrinkled seeds.
Sweet pea	Coloured flowers ...	White flowers.
Wheat and barley	Beardless ears... ...	Bearded ears.
	Non-immunity to rust	Immunity to rust.
Fowls	Rose comb of Wyandottes	Single comb of Leghorns.
Cattle	Absence of horns ...	Presence of horns.

A striking instance of Mendelian work is afforded by the new varieties of wheat established by Professor Biffen. In one of these he has succeeded in combining the vigour of English wheat with the immunity from rust of American Club wheat, while a second unites the former quality with the power of producing 'strong' flour possessed by Canadian Red Fife.

General Remarks on Farm Stock.—The advantages of pure-bred stock are many. In the first place, it costs practically no more—sometimes less—to rear a pure-bred animal than one that is not pure bred. In the next place, in the case of a butcher's animal, there will be far less 'offal' about it, and more substance in the useful parts of the carcass, if it is pure bred.

It is not to be inferred that *any* pure-bred animal will make a desirable parent, simply because it *is* pure bred. Besides this, it should be healthy and of sound constitution—conditions that are not always to be relied upon even in pure-bred animals. The breeder should, moreover, aim at the development of qualities that are useful rather than of those that are merely fanciful. There is plenty of scope for the exercise of the latter art amongst dogs and pigeons and rabbits, but it should be discouraged in the more serious business of breeding

cattle, sheep, and pigs, amongst which the development of a fancy point is only of value when it indicates the simultaneous possession of some more solid quality.

The term **thoroughbred** is used in strictness to denote the purity of lineage of the race-horse. In all other cases, the same idea is conveyed by the term **pure-bred**. Accordingly, the word 'thoroughbred' is used to denote a blood-horse, which is spoken of simply as 'a thoroughbred.' The other term is commonly used as an adjective —for example, a pure-bred Clydesdale, a pure-bred Devon, a pure-bred Southdown, a pure-bred Berkshire. Usually, however, the adjective is dropped, and when it is said that a man has a Hackney stud, or a herd of Shorthorns, or a flock of Shropshires, or a herd of Berkshire swine, it is understood to be pure-bred.

A **cross-bred** animal is the offspring of parents of two distinct breeds. Cross-breeding is an effective means of raising cattle and sheep for butchers' beasts, and fine specimens of cross-bred animals appear at the winter fat-stock shows. The cross can be specified by linking the names of the breeds of the parents together, putting that of the sire first: thus a Shorthorn-Galloway is the offspring of a Shorthorn bull and a Galloway cow. A Hampshire-Oxford sheep is the produce of a Hampshire Down ram and an Oxford Down ewe.

A very useful term, more employed in America than in England, is **grade**. It is applied to animals, one only of whose parents—usually the sire—is pure bred. A Shorthorn grade, for example, is the produce of a Shorthorn bull and of a cow which cannot be referred to any recognized breed. Grade animals are common in the markets.

Breed Records.—Breeders of different classes of live stock have found it conducive to their interests, and favourable to the progress of the breed with which they are concerned, to combine together in societies or associations, and to publish periodically a volume containing the name, pedigree, breeder, owner, etc., of each pure-bred animal. Such a volume is called a Stud Book in the case of horses, a Herd Book in the case of cattle and pigs, and a Flock Book in the case of sheep. In some

cases the volume is published annually, in others less frequently. The Shire Horse Stud Book, the Shorthorn Herd Book, the Oxford Down Flock Book, and the Berkshire Herd Book may be cited as examples. These books, then, are registers or records, and breeders of pure-bred stock take special care to get their animals properly entered. In the case of old-established books, it is possible to trace the pedigree of living animals back through numbers of generations.

Gestation.—The time during which a female carries her young is termed the *period of gestation* (Lat. *gestatio*, a bearing or carrying). The actual length of the period varies slightly in all animals, but in the case of farm stock is, on the average, as follows: mare, 340 days; cow, 285 days; ewe, 144 days; sow, 120 days. Or, roughly, the mare, eleven months; the cow, nine months; the ewe, five months; and the sow, four months.

CHAPTER XXIII.

HORSES: THEIR BREEDS, FEEDING, AND MANAGEMENT

THE native breeds of Horses recognized in this country are known as—

Thoroughbred	Cleveland	Shire
Hackney	Coaching	Clydesdale
Pony		Suffolk

The Thoroughbred, Hackney, Pony, Cleveland, and Coaching, are breeds of *light horses*. The Shire, Clydesdale, and Suffolk are breeds of *heavy horses*.

THOROUGHBRED (Plate IV., 1).—A thoroughbred stallion should be about 16 hands in height, with oblique shoulders, fine withers, a long muscular neck joining on to deep shoulders, a lean masculine head (broad between the eyes, with the latter well developed), short

and deep back, barrel well ribbed up, and well-sprung ribs; with muscular quarters and thighs, flat bone below the knee, fine sinews standing well apart behind the cannon-bone (which should not be too long between the knee and pastern), and well-formed big knees and hocks. The feet should be open at the heels, not too large, and joining on to pasterns which are not too long, but sloping.

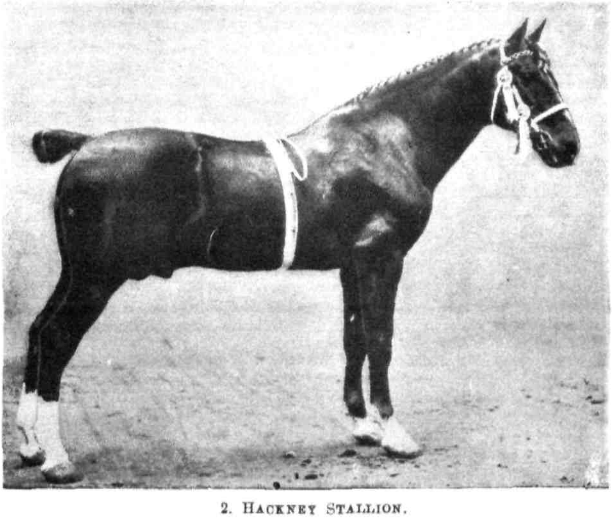
Most of the thoroughbreds of the present day are built too much on the lines of a greyhound, and they have lost much of their constitution and stamina by being trained too soon and entered as two-year-olds in so many short-cut races of about six furlongs, whereas if they were allowed to mature before being raced, and then not less than ten furlongs, it would be less of a scramble in getting off, which has such a demoralizing effect on the jockeys as well as the youngsters engaged. There are not enough cup courses of from two or three miles for more mature animals, which would bring out the staying powers and so much improve the breed. It is said, with some truth, that it costs nowadays so much for the raw material that owners would not care to speculate if they had to keep a yearling until he was three years old before he began to earn anything, so he has to begin racing at two years old, and the whole breed suffers in consequence.

Hunters are often thoroughbreds, but many are only partly of this strain, and produced by crossing thoroughbred stallions with mares of various kinds—*e.g.*, Cleveland Bays, or by two thoroughbred crosses on small Clydesdales or Suffolk Punches. A considerable proportion of thoroughbred blood in the dam, however, is desirable, and gives a larger proportion of offspring suited to hunting purposes.

A good type of hunter should be thick and strong on the back and loin, with long powerful quarters and muscular thighs, and hocks neatly shaped and clean. The head should be long, lean, and blood-like, and the eye full. A mahogany-brown colour is in high favour, then black, bay, or dark chestnut. Greys, roans, and light chestnuts are less saleable.

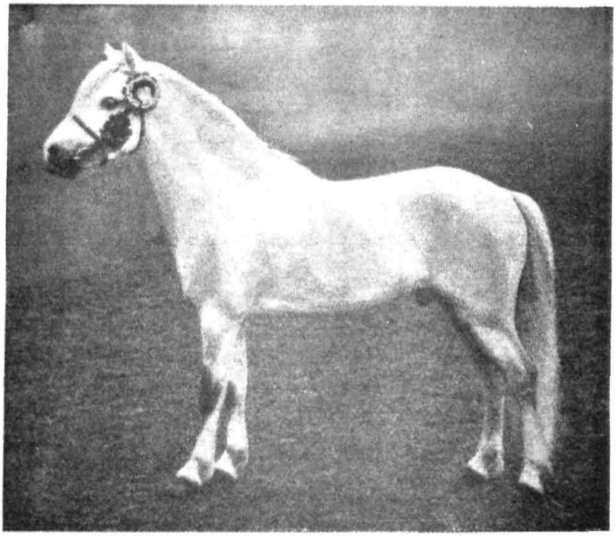
PLATE IV.

1. Thoroughbred Stallion.



2. Hackney Stallion.

PLATE IV.—*continued.*



3. WELSH MOUNTAIN PONY STALLION.

4. CLEVELAND BAY STALLION.

'Size, in addition to power, stamina, and action, is a great desideratum in any hunter, for a big horse possesses the charm of making the fences look smaller than they really are, and *vice versâ*, and therefore a little horse will not command the price that would be given for a bigger one, however clever he may look or be. Every hunter should gallop and be safe and quick at his fences. He must possess freedom of the shoulder and a knack of bending his hocks, above all things.'—(Professor Wortley Axe.)

Hackney (Plate IV., 2).—The term *nag*, applied to the active riding or trotting horse, is derived from the Anglo-Saxon *knegan*, to neigh. The Normans brought with them their own word, *haquenée*, or *hacquenée*, the French derivative from the Latin *equus*, a horse, whence the word Hackney. Both Nag and Hackney continue to be used as synonymous terms. Frequent mention is made of Hackneys and Trotters in old farm accounts of the fourteenth century.

The first noteworthy trotting Hackney stallion of the modern type was a horse foaled about 1755, and variously known as the Schales Horse, Shields, or Shales, and most of the recognized Hackneys of to-day trace back to him. The breeding of Hackneys is extensively pursued in the counties of Norfolk, Cambridge, Huntingdon, Lincoln, and York.

Of modern Hackneys, some are riding horses and some are driving horses, but in recent years more attention has been given to the latter. The breeder's object is to produce an animal which is saleable at an early age, which can be bred and reared at moderate expense, and which can be broken in without much risk. Excellent results have followed the use of Hackney sires upon half-bred mares, the latter being the offspring of thoroughbred stallions and trotting mares. The Hackney is noted throughout the world for his high and bold action, his courage, great amiability, grand formation, soundness, and power of transmitting his good qualities (especially action) with whatever breed of mare he is crossed.

The movement, or, as it is termed, the 'action,' of

the Hackney is all-important. He should go light in hand, and the knee should be so elevated and advanced during the trot—his natural pace—as to be seen by the rider projecting beyond the breast, whilst, before the foot is put down, the leg should be well extended. Above all, the Hackney should possess good hock action, as distinguished from mere fetlock action, the propelling power depending upon the efficiency of the former.

To be classed as a Hackney an animal must be over 14 hands high—that is, exceeding 56 inches. The pony—next to be considered—must, on the contrary, not exceed 14 hands. A horse's height is measured at the withers, by the vertical line falling just behind the fore-legs.

PONY (Plate IV., 3).—The native breeds of pony include—

English	New Forest	Shetland
Dartmoor	Welsh	Highland
Exmoor		

PONIES range in height from 14 hands down to 8½ or 9 hands, many Shetland ponies not exceeding the latter. As in the case of the Hackney, so with the pony, thoroughbred blood has been used, and with manifestly good results. A great object with the pony breeder is to control size—to compress the most valuable qualities into the least compass. He endeavours to breed an animal possessing a small head, perfect shoulders, true action, and good manners. A combination of the best points of the Hunter with the style and finish of the Hackney produces a class of weight-carrying pony which is always saleable.

CLEVELAND BAY (Plate IV., 4).—There is no breed of horses in which are combined so fully all the most useful and ornamental equine qualities—beauty with strength, courage with docility, stamina and speed, and those impressive powers which it inherits, and owes to long and pure descent. It is to this breed that North and South America and the Colonies, as well as Continental countries, have long had recourse, to improve their horses, and with such marvellous results. Unhappily the foreign demand has tended always to keep down the numbers of

the best representatives of the breed at home. There is no superior 'general utility horse' to the Cleveland Bay; and there is no better base or foundation for crossing to obtain hunters, cavalry horses, and harness horses. It is the only breed which can be crossed with blood and give added bone, strength, stamina, and action, without at the same time seriously detracting from appearance, quality, and activity.

Coaching.—The Yorkshire coach-horse, derived from the Cleveland Bay over a century ago, is extensively bred in the North and East Ridings of the county, and the thoroughbred has taken a share in its development. The colour is usually bay or brown, the legs being black. The mane and tail are abundant, but not curly, and black in colour. A fine head, sloping shoulders, strong loins, lengthy quarters, high-stepping action, flat legs, and sound feet are looked for, and there should be an abundance of bone and muscle. The height varies from 16 hands to 16 hands 2 inches.

Shire (Plate V., 1).—In the closing years of the eighteenth century, Arthur Young, describing his agricultural tours, made reference to the large black old English horse, 'the produce principally of the *Shire* counties in the heart of England.' Long previous to this, however, the word Shire, in connection with horses, was used in the statutes of Henry VII. By the various names of the War Horse, the Great Horse, the Old English Black Horse, and the Shire Horse, the breed has for centuries been cultivated in the rich fen-lands of Lincolnshire and Cambridgeshire, and in many counties to the west.

The Shire is the largest of draught horses, the stallion commonly attaining a height of 17 hands or more. Though the black colour is frequently met with, bay and brown are now more usually seen. The lighter colours, such as chestnut, roan, and grey, are not viewed with much favour. With their immense size and weight —1,800 lb. to 2,000 lb.—the Shires combine great strength and they are withal docile and intelligent. They stand on big massive legs, 11½ to 12½ inches below the knee, with 1½ to 2 inches more below the hock.

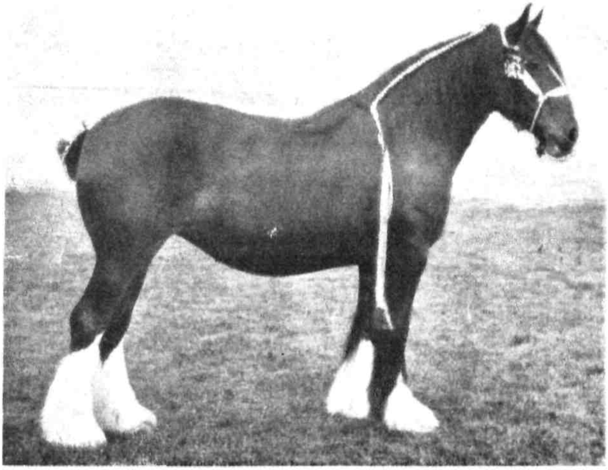
There is a plentiful covering of long hair extending down the back of the limbs from knees and hocks to pasterns. The head is of medium size, and broad between the eyes. The neck is fairly long, and well arched on to the shoulders, which are deep and strong, and moderately oblique. The chest is wide and full, the back short and straight, the ribs are round and deep, the hind quarters long, level, and well let down into the muscular thighs. The cannon bones should be flat, heavy, and clean, and the feet wide, tough, and open at the heels; pasterns with sufficient slope, but not long and consequently weak. A good type of Shire horse combines symmetrical outline, and straight, free, forward action, with clean, heavy, flat bone, and plentiful hair, not wiry, but strong and decided, without any tendency to woolliness.

CLYDESDALE (Plate V., 2).—The home of this Scotch breed of heavy horses is in the valley of the Clyde. The Clydesdale is somewhat smaller than the Shire, the average height of the former being about 16 hands 2 inches. The shoulder is more oblique than is the case with the Shire. The favourite colour is brown, particularly if of a dark shade, or dappled. Black is also a common colour, but grey is not encouraged. White markings on one or more of the legs, with a white star or stripe on the face, are quite usual. The 'feathering'—that is, the development of silky hair on the backs of the legs—is a point to which Clydesdale breeders attach much importance, it being regarded as an indication of strong, healthy bone. The bones of the legs should be short, flat, clean, and hard. With symmetry, activity, strength, and endurance, the Clydesdale associates a good temper and willing disposition, and is easily broken to harness.

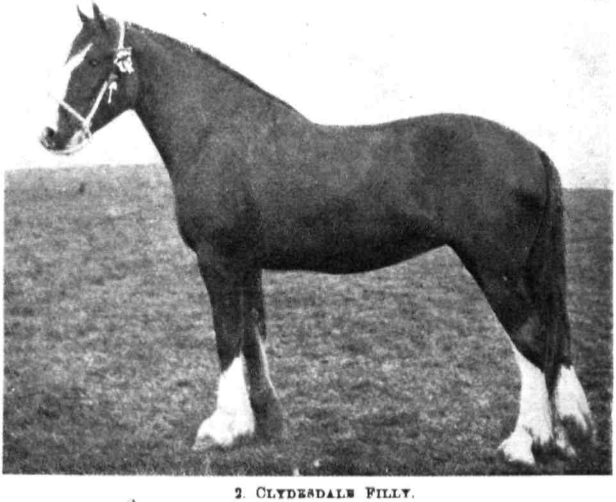
The breed is in great demand for export. The following figures of export certificates issued by the Breed Society are of interest:—

1903	411	1907	1172	1911	1617
1904	536	1908	531	1912	1348
1905	653	1909	1349	1913	837
1906	1317	1910	1531		

PLATE V.

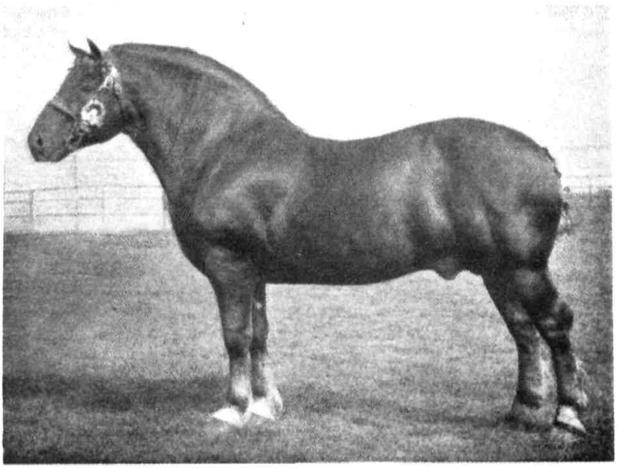


1. Shire Filly.



2. Clydesdale Filly.

PLATE V.—*continued.*



3. SUFFOLK STALLION.

SUFFOLK (Plate V., 3).—Whilst the Shire and the Clydesdale present many points in common, the Suffolk is a horse which is quite distinct from either. In height it ranges from 16 hands to an occasional 17 hands, and stands on short legs, free from the 'feather' which is so much admired in the two other heavy breeds. How long the Suffolks have been associated with the county after which they are named is unknown, but they are mentioned as long ago as 1586 in Camden's *Britannia*. A striking testimony to the purity of the race is found in the fact that they always breed true to colour. The Suffolk Horse is always a chestnut, although the shade may vary from the light sorrel to the dark mahogany. Owing to the purity of the breed it has been found of considerable value for crossing with native mares in the Colonies and America, and consequently of recent years an increasing export demand has been established. The Suffolk is of a hardy constitution and an easy keeper, when mature weighing up to 2,400 lb. Owing to his deep well-ribbed-up appearance, he is known as the Suffolk Punch.

FEEDING AND MANAGEMENT OF HORSES

Treatment of the Foal.—When a mare gives birth to a young animal she is said *to foal*, and the offspring is called a *foal*—a *colt* foal, if a male; a *filly* foal, if a female. She suckles the foal for five or six months, during which time it runs with its dam, occasionally accompanies her in her work, and learns to graze, and to partake of such fodder as crushed oats and bran—nitrogenous foods that help the young creature to build up its muscle. At the end of the period named, the foal is separated from the mare and weaned. Its diet then consists of oats, bruised or whole, and hay, and it should have two or three meals a day, with a little bran or boiled linseed added at the evening meal. If skim-milk from cows is available, it may be given to the foal for some time after weaning, and, though housed at night, the foal may have a run on a pasture during daytime

A foal will thrive better in company with other foals than if kept alone. It should be accustomed to the halter even before it is weaned, and later to harness. Kind but firm treatment will be found more effectual than rough usage, and the young animal should be taught to obey the voice rather than be driven with the whip. A good ploughman works his horses almost entirely by the voice.

Soft, spongy pastures, growing a rank, but good herbage, are the best kinds of grass land for rearing young horses during summer, as they favour the growth and expansion of the hoof. In winter the young animals are usually housed, but have access to large airy yards, as exercise is absolutely essential to their healthy development. Some of the most successful breeders, however, prefer to let the foal run all the winter on grass, sheds being available for shelter in bad weather and for feeding in. Regular feeding with generous food must be continued. Linseed cake, beans and peas, oats and hay, with a few cut swedes, are suitable foods.

Breaking-in to Work.—At the age of two to three years the young animal should be broken to regular work on the farm, a start being made in the plough team between two steady old horses. A heavy roller is also useful for the same purpose. It is not wise, however, to do much carting with a young horse, or to work it on the hard roads till it is between four and five years of age.

The feeding and management of the mature horse must be determined strictly in accordance with the objects for which it is kept. Whether used for riding or driving, or for purposes of draught, in towns, or on farms, the horse is a *working animal.* The performance of work involves, especially in the case of under-fed animals, a waste of tissue, and, to make this good, nitrogenous food is necessary.

But the performance of work equally results in the evolution of heat, and this is largely due to the oxidation of carbon. Consequently the horse requires a liberal supply of carbonaceous food along with the nitrogenous material. For horses of speed—racers and hunters—

beans, oats, and hay are found most suitable. For draught animals a ration containing a somewhat greater proportion of carbohydrates will be found more economical, and a certain amount of straw may be fed in the form of chaff.

The basis of a winter ration for a farm horse may be taken at about equal weights of oats and hay, say—

Oats, 12 lbs. per day	=	84 lbs. (or 2 bushels)	per week.
Hay, 16 lbs. ,,	=	112 lbs. (or 1 cwt.)	,,

In practice a certain amount of the hay is replaced by straw, which is usually fed as chaff, and in some of the northern counties the farm horses are fed on oat straw and oats alone without addition of hay. In some cases where there is a good market for oats it may be more economical to use a mixture of maize and beans in the proportion of 2½ of the former to 1 of the latter, especially when maize is at a reasonable price. When maize is used it is advisable to give clover hay of good quality along with it in order to supply a sufficient quantity of flesh-formers in the diet.

A horse has not the capacious stomach of an ox or a sheep, neither has it the power of ruminating its food. For these reasons, it is necessary that horses should have their food in a more concentrated form and at regular intervals.

All corn is best given crushed or bruised along with hay or straw chaff, so as to prevent bolting and to ensure complete mastication.

The quantity of food given at any season should be regulated by the amount of work on hand, and every increase in work should be met with an increase in the quantity of food.

Spring and autumn are two busy periods, and farm horses, as a rule, should receive a more liberal ration at these times.

Digestibility is promoted by well mixing the chaff and other ingredients together, and moistening the mass with water the day before it is required for use. A moderate allowance of roots, or other green foods as they come in season, should be given. A lump of rock-salt

should always be kept either in the manger or in any convenient place where the animals may have access to it. Regularity of feeding should be practised, moderate meals at fairly short intervals being, on account of the nature and duties of the horse, preferable to heavier meals at longer intervals. An abundant supply of pure water, soft rather than hard, should always be available.

The stable should be commodious, freely ventilated, well-drained, and withal warm and comfortable. It is most important that stable drains should be on the surface, and should empty into traps outside the stable. A horse in a fairly warm stable will require less food for the maintenance of the heat of the body than if kept in a cold, draughty building. At the same time, it is a serious error to secure warmth at the sacrifice of pure air. Horses often incur more risks of ill-health in badly constructed stables than they do in the field, and when it is remembered that, in winter time, farm horses often spend sixteen hours out of the twenty-four in the stable, the importance of a healthy dwelling-house is at once seen to be very great.

COST OF HORSE LABOUR

As the basis of all charges for tillage operations depends on the cost of horse labour it will be worth while here to make an estimate of the actual cost to the farmer of keeping a working horse for a year. The question of feeding must first of all be considered, and it will be found that the rations suggested below approximate very closely to those used on well-managed farms throughout the country:—

Cost of Feeding.

Winter.—Say, some 32 weeks—October to May.

	s.	*d.*
2 bushels of oats per week at 2*s.* 3*d.*	4	6
1 cwt. of hay per week at 3*s.*	3	0
1 cwt. of straw per week at 9*d.* ... ... (for chaff and litter)	0	9
Linseed and a few roots	0	3
	8	6

COST OF FEEDING—*continued.*

Summer.—Say, some 20 weeks—May to October.

	s.	*d.*
1 bushel oats at 2*s.* 6*d.*	2	6
Grazing at 2*s.* 6*d.*	2	6
Cut fodder straw, say	1	6
	6	6

This, on the average, would be a little over 7*s.* 6*d.* per week throughout the year.

The other items connected with keeping a farm horse may be estimated as follows:—

Cost of Keeping a Farm Horse for a Year.

	£	*s.*	*d.*
Food	20	0	0
Shoeing and share of blacksmith's work connected with team, say	2	0	0
Depreciation of harness	1	10	0
Depreciation on value of horse, 10 per cent. on £40	4	0	0
Incidentals, including veterinary attendance and medicine, rent of stable and extra labour, say	3	0	0
	£30	10	0

According to the class of soil and the weather, the total number of horse days in the year will vary, as a rule, on farms in different parts of the country from 220 to 260 full working days. Taking the average as 240 days, and dividing this into £30 10*s.*, we see that the actual cost of horse labour per day amounts to a little over half-a-crown.

If an extra 5*d.* to 6*d.* per day is allowed for loss of time and upkeep of implements of tillage, such as ploughs, cultivators and harrows, the total cost per horse works out at 3*s.* per day.

Three shillings per horse per day, therefore, seems a fair charge for a farmer to allow when estimating the cost of his cultivations.

The amount allowed for depreciation on the original value of the horse in the above calculation may in some cases appear too high. Thus in some cases where it is the practice to breed, rear, and break-in young horses, working them for a year or two before selling them for town work, the cost of horse labour to the farmer is considerably reduced.

Again, where teams of aged horses are used, they may go on for a number of years with scarcely any depreciation in value.

CHAPTER XXIV.

CATTLE: THEIR BREEDS, FEEDING, AND MANAGEMENT

THE native breeds of cattle recognized in this country include:—

Shorthorn	Longhorn	Jersey
Hereford	Red Poll	Guernsey
North Devon	Aberdeen-Angus	Kerry
South Devon (Hams)	Galloway	Dexter
Sussex	Highland	Lincoln Red } p. 656
Welsh	Ayrshire	British-Holstein } p. 656

With three exceptions (Shorthorn, Longhorn, and Red Poll) these are all distinguished by geographical names, which indicate what may be called the 'homes' of the breeds, and which serve to show where they severally originated. The Shorthorn, Hereford, North Devon, South Devon, Sussex, Longhorn, and Red Poll breeds belong to England. The Aberdeen-Angus, Galloway, Highland, and Ayrshire breeds belong to Scotland. The Jersey and Guernsey are the Channel Islands breeds, and the Kerry and Dexter are Irish breeds.

Some breeds of cattle are specially distinguished as

beef-makers. These include the Shorthorn, Hereford, North Devon, Sussex, Welsh, Aberdeen-Angus, Galloway, and Highland.

Certain breeds have become famous as milk-producers, and make excellent dairy cattle. Such are the Shorthorn, South Devon, Longhorn, Red Poll, Ayrshire, Jersey, Guernsey, Kerry, Dexter, and British-Holstein.

Besides the Shorthorn, however, the South Devon, the Welsh, the Red Poll, the Dexter, Kerry, and one or two other breeds are claimed, by those who have bestowed care and attention upon their improvement, as useful for both beef-producing and dairy purposes.

The biggest and heaviest cattle come from the beef-making breeds, and at the Christmas fat-stock shows huge oxen may sometimes be seen weighing a ton or more each, these, however, being often cross-bred. Very large beasts, if pure bred, usually belong to either the Shorthorn, Hereford, Sussex, Welsh, Aberdeen-Angus, South Devon, or Galloway breeds. The North Devon, Red Poll, and Guernsey are medium-sized cattle; the Ayrshires are smaller. The Jerseys are small graceful cattle, but the two Irish breeds furnish the smallest cattle of the British Isles.

As to colour, red characterizes the Lincoln Red, North Devon, Sussex, and Red Poll. Black is the dominating colour of the Welsh, Aberdeen-Angus, Galloway, Highland, Kerry, and Dexter. A yellowish colour is common in the Guernsey and South Devon breeds. Various shades of fawn colour are seen in the Jersey cattle. The Herefords, though with red bodies, have white faces, manes, and dewlaps, whilst white prevails to a greater or less extent in the Shorthorn, Longhorn, and Ayrshire breeds. The Shorthorn breed is exceedingly variable in colour; pure bred specimens may be either red, or white, or roan, or may be marked with two or more of these colours, the roan resulting from a blending of the white and red. Black is not seen in a pure bred Shorthorn.

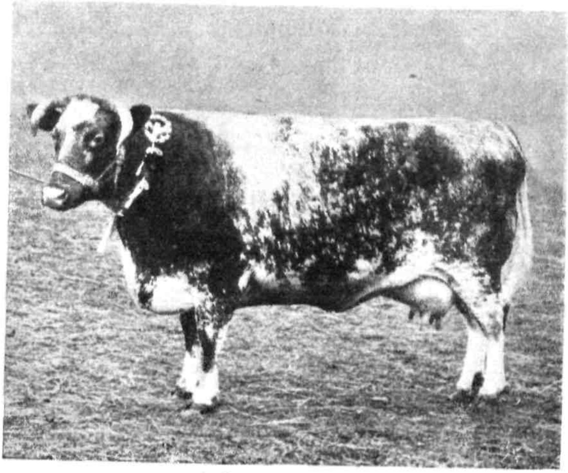
Shorthorn (Plate VI., 1 and 2).—This is the most widely distributed of all the breeds of cattle both at home and abroad. Although its origin is lost in antiquity, it may

be said to have been brought into prominence during the last quarter of the eighteenth century by the exertions of the brothers Charles and Robert Colling, who, by careful selection and breeding, greatly improved the Shorthorn cattle of the Teeswater district, in the county of Durham. It is indisputable that the efforts of the brothers Collings had a profound influence upon the fortunes of the breed, which is still termed the 'Durham' breeds in most parts of the world save in the land of its birth. Other shrewd breeders took the Shorthorn in hand and established famous strains, the descendants of which can be traced down to the present day. Of such breeders, the best known are Thomas Booth, of Warlaby and Killerby, in Yorkshire, who originated the 'Booth' strains of Shorthorns; Thomas Bates, of Kirklevington, in Yorkshire, by whom the 'Bates' families were established; and, in later years, the brothers Amos and Anthony Cruickshank, of Sittyton, Aberdeenshire, the originators of the 'Cruickshank' strains of cattle. When Shorthorn breeders of to-day talk of 'Booth' blood, of 'Bates' blood, or of 'Cruickshank' blood, they refer to animals bred from the respective herds of these breeders.

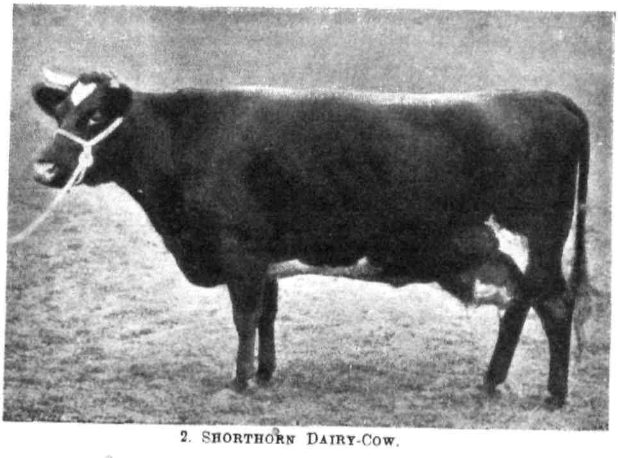
Shorthorns vary in colour, ranging from a bright or rich red to pure white, The most popular colour is a mixture of the two forming a roan, which may, however, vary from light roan (nearly white), in different grades of colour, to dark roan (almost red).

The breed is distinguished by its symmetrical proportions and by its great bulk on a comparatively small frame. The head of the male is somewhat short, broad across the forehead, but gradually tapering to the nose; it should show strength and masculine character, the nostril full and prominent, the nose itself of a rich flesh colour; eyes bright, prominent, and placid. The head, crowned with curved and rather flat horns (unusually short in comparison with other British breeds), is well set into a lengthy, broad, muscular neck; the chest wide, deep, and projecting; shoulders fine, oblique, and well formed into the chine; fore-legs short and wide apart, with the upper arm large and powerful; barrel round,

PLATE VI.

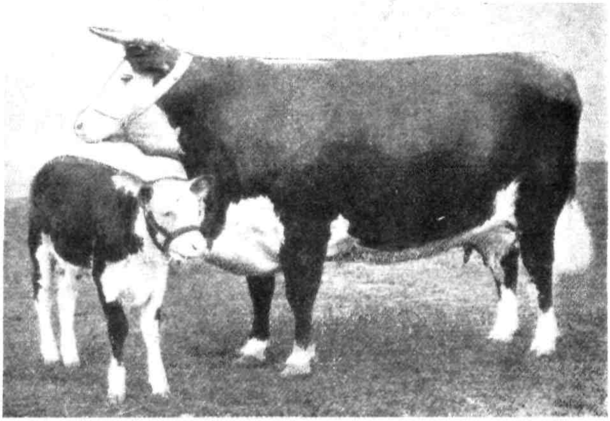


1. Shorthorn Cow

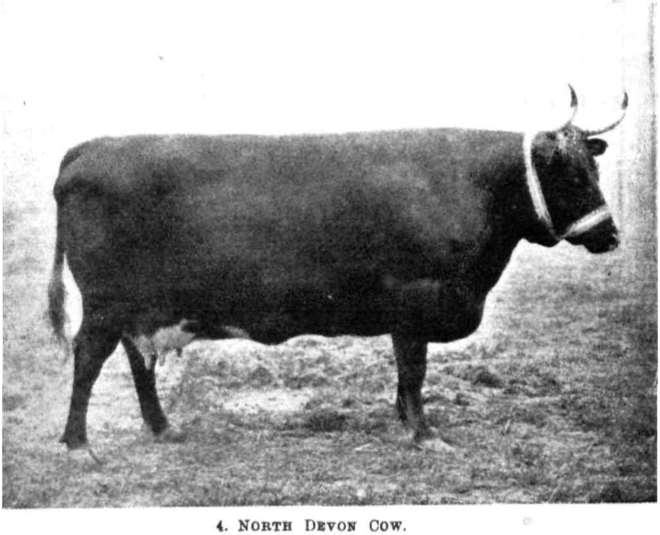


2. Shorthorn Dairy-Cow.

PLATE VI.—*continued.*



3. HEREFORD COW AND CALF.



4. NORTH DEVON COW.

deep and well ribbed up towards the loins and hips, which should be wide and level; back straight from the shoulders to the setting of the tail; the hind quarters lengthy, but well filled up; the hair plentiful, soft, and mossy, with a hide not too thin, and having a fine and mellow touch.

The female possesses nearly the same characteristics as the male, except that the head is finer, longer, and more tapering, the neck thinner and altogether lighter, and the shoulders more inclined to narrow towards the chine. The udder should be square and full, and the teats placed wide apart.

The popularity of the Shorthorn arises from its unrivalled range of adaptability, thriving in all countries and all climates. It is unsurpassed as a beef producer, being remarkable for its quick-feeding properties and early maturity, animals of the breed attaining to very great weights. It is not less well known for the production of milk. In some herds the production of beef is the chief object, whilst in others the milking qualities are specially considered, and it is this dual capacity for the production of beef and milk which has led to the Shorthorn being designated 'the dual purpose animal.' Shorthorn cows have yielded upwards of six gallons of milk per day, and 2½ lb. of butter in twenty-four hours. Three-fourths of the milking cattle in Great Britain and Ireland are Shorthorns, a striking testimony to the utility of this breed for dairy purposes, its value in this respect being enhanced by its ability to put on flesh quickly when dry, and become a good carcase of beef, a quality not possessed by any other breed in the same degree. One characteristic of the Shorthorn breed of cattle is its great *prepotency—i.e.*, the power to stamp its own good qualities on any and every other breed on which it may be crossed. For crossing purposes, therefore, the breed is unrivalled, and there is more of the Shorthorn than of any other blood in the majority of cross-bred cattle. Improvement has followed the use of the Shorthorn in size, form, quality, rapidity of growth, and aptitude to fatten at an early age. In this country its importance exceeds

that of any other breed, whether it be viewed as a grazier's beast or a dairyman's cow, and in numbers it probably equals those of all other breeds taken together. Shorthorns may be seen at nearly all the fairs and cattle markets in this country, a statement that can be made of no other breed.

Hereford (Plate VI., 3).—The cattle of this breed are typical of Herefordshire and the adjoining counties. The bull should have a moderately short head, broad forehead, and horns nearly resembling the colour of wax, springing straight out from the side of the forehead and slightly drooping; those with black tips or turning upwards are not regarded with favour; the eye should be full and prominent, the nose should be broad and clear (a black nose is objectionable), the body should be massive and cylindrical on short legs, the outline straight, chest full and deep, shoulder sloping but lying well open at the top between the blades, neck thick and arched from the head to the shoulders, ribs well sprung, flank deep, buttocks broad and well let down to the hocks, the tail neatly set and evenly filled between the setting of the tail and the hip bones, which should not be prominent, the whole carcase should be evenly covered with firm flesh, the skin should be thick and mellow to the touch, with soft curly hair of a red colour, but the face, top of neck, and under-parts of the body, should be white.

The same description would apply to the cow, excepting that she should be grown upon more feminine and refined lines, the head and neck being less massive, and the eyes should show a quiet disposition. The Hereford cow under the system of management usually pursued in Herefordshire, on the North American ranch, and on the South American estancia—that is, allowing each cow to raise her own calf, both running together in the pastures, does not develop the milking properties, but there are many instances of Hereford cows brought up to the pail making excellent dairy cattle, the milk being very rich.

Herefords are practically immune from tuberculosis, only two per cent. reacting in a large number tested

each year. They also stand the drought in dry countries better than any other breed.

The Hereford is essentially a beef breed, and reaches maturity at an earlier age and at less cost than any other breed. The steers readily fatten at two years old on grass alone, and in the summer months they command the top price in the London market.

NORTH DEVON (Plate VI., 4).—The cattle of this breed—the 'Rubies of the West,' as they are often termed, in allusion to their colour—are reared chiefly in Devon and Somerset. They are of a whole red colour, the depth and richness of which varies with the individual, and which in summer becomes mottled with darker spots. The skin is typically orange-yellow, but orange-red inside the ears. They stand somewhat low, are neat, compact, and plump, possess admirable symmetry, and, though they do not attain the size of the Shorthorn or the Hereford, yet, taking their height into consideration, they perhaps weigh better than either. In the male animal the thick-set horns project straight out at right angles to the length of the body; in the female they are more slender, and often curve neatly upwards. Being fine-limbed, active animals, they are well adapted for grazing the poor pastures of their native hills, and they turn their food to the best account, yielding excellent beef. They have not attained much celebrity as milch kine, for, though their milk is of first-class quality, its quantity is usually small. Attempts are being made to improve the milking qualities, and in time they are likely to become a general utility breed.

SOUTH DEVON (or HAMS) (Plate VII., 1).—Originating in the southern portion of Devonshire, the breed has spread throughout Devon and Cornwall, and since the establishment of the Herd Book, in 1890, these cattle have been exported in large numbers to South Africa, the Argentine, and Australia. They are claimed to be the heaviest cattle known, steers of two years of age commonly turning the scale at 7½ cwt.; their beef is well interleaned, and the cows are heavy milkers, with a high percentage of butter fat. Colour, from dark red to orange; face long; horns white and spreading; and

constitution hardy. They stand the tuberculin test well, and possess the characteristics of the typical butcher's and dairyman's animal.

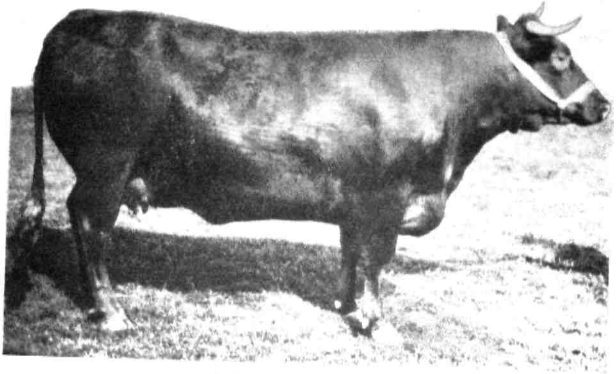
Sussex (Plate VII., 2).—This old-established breed, which takes its name from its native county, is in great favour on the wealden clays and the marshlands of Sussex, Kent, and Surrey. It has many points of resemblance to the Devon breed. The Sussex cattle, however, are bigger, less graceful in outline, and of a deeper brown-chestnut colour than the Devons.

They are one of the hardiest of breeds, able to thrive and do well under the most unfavourable circumstances as regards food, soil, and climate, and practically free from disease. They are highly valued in their native districts, where they have been rapidly improved during recent years. They are essentially a beef-producing breed, the cows having little reputation as milkers. By stall-feeding they can be ripened off for the butcher at an early age. The Sussex cattle are said to 'die well'—that is, to yield a large proportion of meat in the best parts of the carcase.

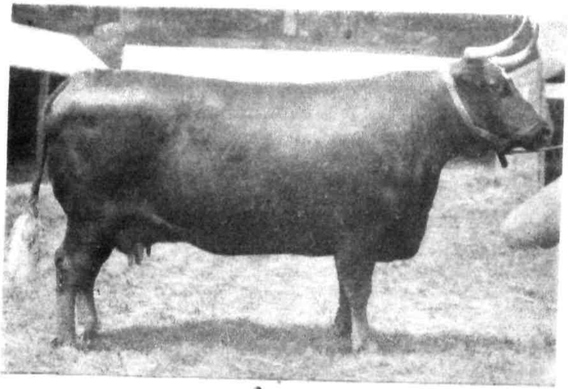
Welsh cattle (Plate VII., 3) constitute one of the most ancient breeds, of which several varieties are recognized in Wales. They are mostly black in colour, though a chocolate or brown tinted black is favoured in some districts. There are a few white hairs in the tip of the tail and near the udder in the cow. The long horns are of a deep blood-tinted yellow, with dark points. When fully grown they make big, ponderous beasts, and, though they do not mature very rapidly, their beef is of prime quality, being firm and nicely grained. The cows often acquire considerable reputation as milkers. As grazier's beasts they are well known in the Midland counties of England, where, under the name of Welsh Runts, large herds of bullocks are fattened upon the pastures, or 'topped up' in the yards in winter. Welsh cattle are extremely hardy, and it is claimed that they are unusually free from tuberculosis.

Longhorn (Plate VII., 4).—Before the advent of the Shorthorn this grand old breed was widely spread over England and some parts of Ireland, not only in the

PLATE VII.

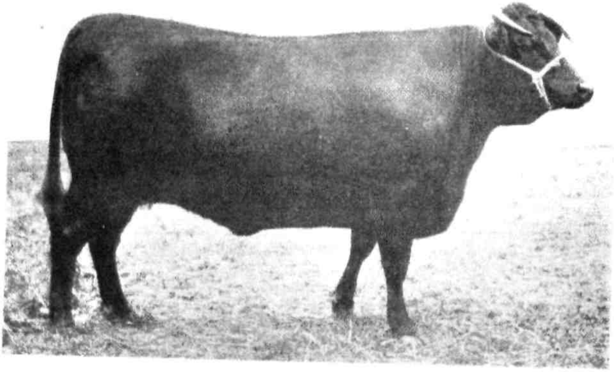


1. South Devon Cow.

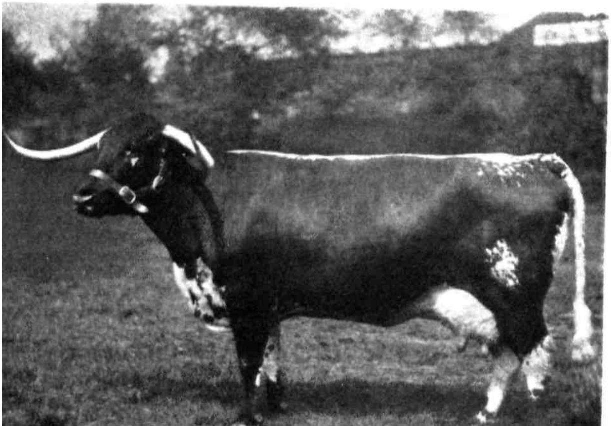


2. Sussex Cow.

PLATE VII.—*continued.*



3. Welsh Heifer.



4. Longhorn Cow.

Midlands of England, but also on the bleak pastures of Cumberland and Westmorland. They were invaluable to cheese-makers, as their milk produced so much curd. Bakewell, of Dishley, in his day did much to improve them, and they soon realized high prices; but for want of greater care in breeding, and with the newly-arrived fashionable Shorthorn taking hold of popular fancy, the old breed became greatly reduced. During the past twenty years they have much improved, and are slowly, but surely, winning their way back into public favour. They are splendid milkers, weighty beasts, producing first-rate beef, and possessed of marvellous constitutions. An ox of this breed, when matured, is a majestic animal, whilst the crosses make the best of steers; first-cross cows, too, are magnificent milkers. Longhorn milk, as proved at the Royal Agricultural Society of England's Show, 1910, contains no less than 4·72 butter fat, and was only very slightly exceeded by three Jersey cows in a total of seventy cows tested, and with a butter yield of 2 lb. 2¾ oz. per diem.

The cows have wide-branching horns, and many have horns incurved. The cattle are preferred to be of a mulberry, clay, or brindled colour, with a white line along the spine. The last point is absolutely essential.

Red Poll (Plate VIII., 1).—This is the only hornless breed of English cattle, originating by the skilful mating for over one hundred years of the old Norfolk and Suffolk Red Poll. An excellent type of animal has been evolved, which combines the red colour and beef-producing quality of the Norfolk with the milk production of the Suffolk. The quality of the milk given has always borne a good reputation. At the London Dairy Show, 1909, the average percentage of butter fat given by the breed was—

	Morning.	Evening.
Cows	3·54 . .	3·51
Heifers	4·46 . .	3·90

one heifer giving over 5 per cent.

In the Herd Book of 1909 eleven herds publish records of 220 cows; of these—

33 cows average over 8,000 lb. of milk per annum.
8 ,, ,, ,, 9,000 ,, ,, ,,
11 ,, ,, ,, 10,000 ,, ,, ,,

Two small herds average 8,000 lb. and the largest herd 7,291 lb. per cow.

Early maturity is evidenced by the ages and weights of winning steers at Smithfield Fat Cattle Show, 1909:—

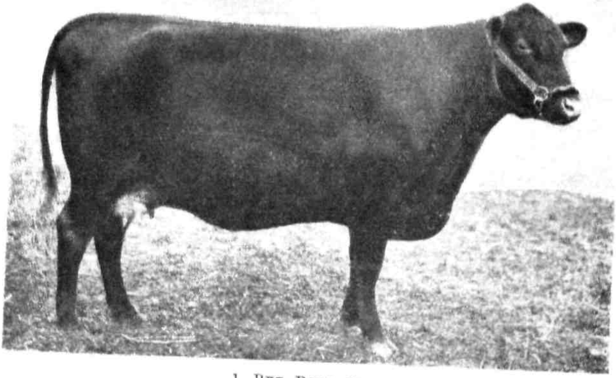
Years.	Months.	Days.	Cwts.	Qrs.	Lbs.
1	10	3	11	3	27
1	9	8	12	—	—
2	3	29	15	—	2
2	11	4	15	—	3

Experience in cross-breeding confirms the expectation that a Red Poll parent mated with a horned breed will produce hornless animals.

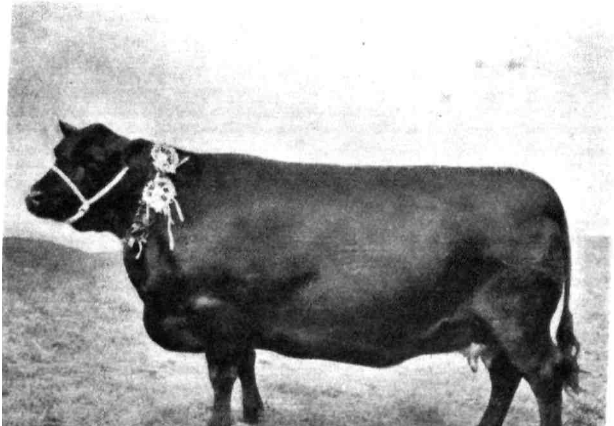
Aberdeen-Angus (Plate VIII., 2).—This black hornless breed is native to the north-eastern counties of Scotland, where it can be traced back as early as the first quarter of the sixteenth century. At the present time it is found in almost every Scotch county, and there are also many herds in England and Ireland. Outstanding names as improvers of the breed are those of Hugh Watson, Keiller, Forfarshire (1808-60), and, for Aberdeenshire, William McCombie, of Tillyfuir, and Sir G. M. Grant, Bart., of Ballindalloch.

Although Aberdeen-Angus cattle have valuable dairy qualities, their milk being rich, the rapid rise in popular esteem of the breed during the last twenty-five years is mainly due to its value in beef production. Combined with early maturing properties and meat of fine quality, the proportion of dead to live weight is unusually high, and holds the record with 76¾ per cent. yield. Aberdeen-Angus cattle are valuable for crossing purposes, a prominent characteristic of the breed being its great

PLATE VIII.

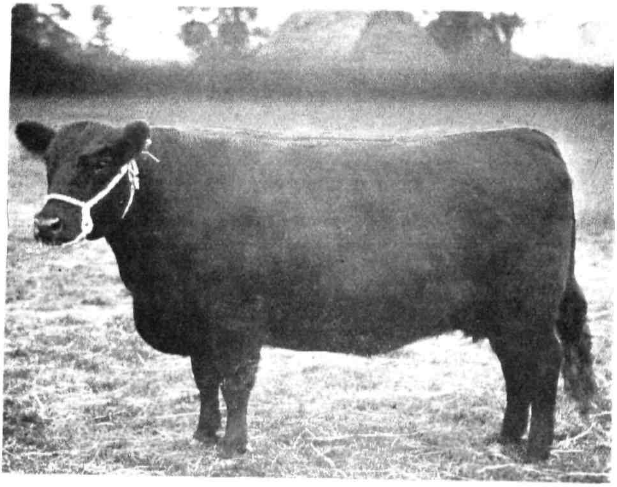


1. Red Poll Cow.

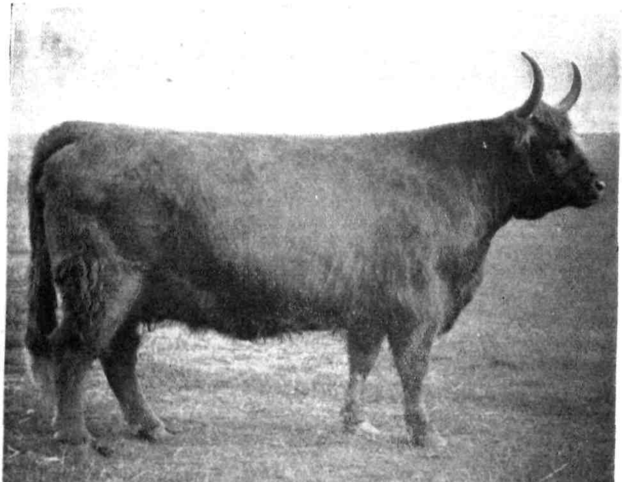


2. Aberdeen-Angus Cow.

PLATE VIII.—*continued.*



3. Galloway Cow.



4. Highland Cow.

potency in transmitting its properties of beef-production and early maturity. It may be added that the breed is highly esteemed in Canada and the United States.

GALLOWAY (Plate VIII., 3).—This hardy and impressive breed of polled cattle took its name from the province of Galloway, which is now confined to the two south-western counties of Scotland, but which in ancient times comprised the six counties which lie to the west of a line drawn from Glasgow to Carlisle on the English border. The same race of cattle has been kept from time immemorial in Cumberland, the most north-westerly county of England.

Galloways as a breed cannot lay claim to any special superiority as milkers. Their milk is rich in quality, but the quantity they give is not large. It is mainly as a beef-producing breed that Galloways have made a name for themselves. The quality of their beef is exceptionally good. In respect of proportion of dead to live weight, Galloways kill unusually well.

The Galloway is admitted on all hands to be the most hardy among British breeds of cattle, except the shaggy, long-horned West Highlander, and the difference between them and that picturesque breed in this important quality is very slight. A large number of Galloways are wintered in the open air in Scotland and the North of England, and this fact, along with their exceptionally vigorous constitutions, are probably the reasons why tuberculosis is almost unknown in the breed.

They not only are now, but have been from time immemorial, polled or hornless. Originally their colours were varied—black, red, brindled, and duns being not uncommon, but for many years, with trifling exceptions of a few dun ones, they have been 'black and all black.'

The remarkable impressiveness of the Galloways is a characteristic for which the breed has long been distinguished where it is known. Alike in respect of colour, absence of horns, and general outline and symmetry, their offspring from cows of other breeds have very closely resembled the black Galloway Polls. When a Shorthorn or other spotted bull is put to Galloway cows

the produce shows a mixture of black and white hairs—'blue-greys,' as they are popularly termed in Britain. Their impressiveness in freeing their produce from horns is marvellous.

HIGHLAND (Plate VIII., 4).—It is thought by many that this picturesque breed is an aboriginal one, but, whether this be so or not, it is certain that no cattle in the United Kingdom have retained in greater uniformity the same characteristic as a distinct breed than the Highlanders have done, and this seems to point to the conclusion that there has been little change in the character of this class of cattle except that produced by a more careful system of breeding. The outstanding characteristic of the breed is its hardiness. Highland cattle seldom suffer from any of the diseases to which other breeds are liable, and tuberculosis is unknown. The hardiness of their constitution enables them to stand a great amount of cold and wet, and during the winter they can be left outside without shed or other artificial shelter. Highland cattle can also exist on pasture where other softer kinds would starve, while no breed thrives better on good pasture. They are also useful in clearing up rough and rank grass left by other stock. The quality of their beef is exceptionally good, and that of well-finished animals meets with a ready sale, and fetches the highest price in the market.

The leading points are as follows: Head proportionate to the body, broad between the eyes, and short from the eyes to the point of the muzzle. Forelock between the eyes wide, long, and bushy. Eyes bright and full. Horns, in the bull, strong, coming level out of the head, slightly inclining forwards, and slightly rising towards the points. The horns of the cow should rise sooner than those of the bull and be somewhat longer, and should have a rich reddish appearance to the very tips. Some prefer that the horns of the cow should come more level from the head, with a peculiar back-set curve and very wide sweep, which gives a graceful appearance. Neck clear and without dewlap below, forming, in the cow, a straight line from head to shoulder. Shoulder thick, filling out greatly as it

descends from the point to the lower extremity of the forearm. Back as straight as possible, fully developed, and rounded from behind the shoulder. Ribs springing boldly out, well rounded and deep. Breadth across the hips very great. Thighs well developed, showing great fulness. Quarters well developed from the hip backwards, square between hips and tail. Legs short and strong both before and behind, bones strong, broad, and straight; legs well feathered with hair, hoofs well set in and large. The animal should be set wide between the fore-legs. Hair very profuse, more particularly on the parts indicated; long, without any tendency to curl. Tail long and well covered with hair at the end. Skin thick, but pliable. Usual colours: black, brindled, red, yellow, and dun.

AYRSHIRE (Plate IX., 1).—This essentially dairy breed was already established in the north of its native county by the end of the seventeenth century, and it is now widely distributed through Scotland, England (especially around London), and North Ireland. Ayrshires are also exported in large numbers to most of the British Dominions, and to the United States. They are characterized by their wedge-shaped formation and 'flecky,' well-defined markings (varying from deep red to light mahogany) on a white ground. Of recent years there has been an increase in white animals, some being all white, save for dark markings on the head and neck. The character of the horns may be gathered from the illustration.

The following are the chief points to be looked for in the breed: Head short, broad forehead, muzzle large, without coarseness, and eyes full and bright; neck fine throughout, of good length, and free from loose skin; forequarters thin and light; the body set on straight, short legs, well apart; the back strong and straight; ribs, long, broad, wide apart, and well sprung, with abdomen capacious, deep, but firmly held up; hindquarters wide, level, and long, hocks wide apart, thighs thin, long, and wide apart; tail long, fine, set on a level with the back. Great stress is placed on the shape of the udder, which should be long, wide, and deep, but

not pendulous nor fleshy, and should be firmly attached to the body. The vessel should extend well up behind, and far forward, quarters even, sole nearly level, and mammary veins large, long, and tortuous, branching and entering large orifices. The teats should be evenly placed, length 2½ to 3½ inches, hang perpendicular, slightly taper, and give a free flow of milk on pressure.

Ayrshire cows yield on the average about 590 gallons of milk per annum, but many are capable of giving from 800 to 1,000. The Ayrshire is peculiarly the cow of the small farmer. Her price is within his reach. She takes kindly to care and attention, and no cow will yield a greater return for labour bestowed on her.

JERSEY (Plate IX., 2).—This race of cattle is native to the island of Jersey, and has been kept pure for many generations by means of stringent importation regulations. It claims to be one of the oldest pure breeds extant, is noted for its dairy qualities and the richness of its milk, the old breeders having turned their attention to these points only, without considering the beef-producing properties of their cattle. The Jersey does not claim to be a dual-purpose cow, and therefore she does not easily put on flesh. She is a great favourite in England, where her value as the best butter-producing cow has been demonstrated in the public butter test trials that have been carried out during the past twenty-four years, the average results from which are as follows—

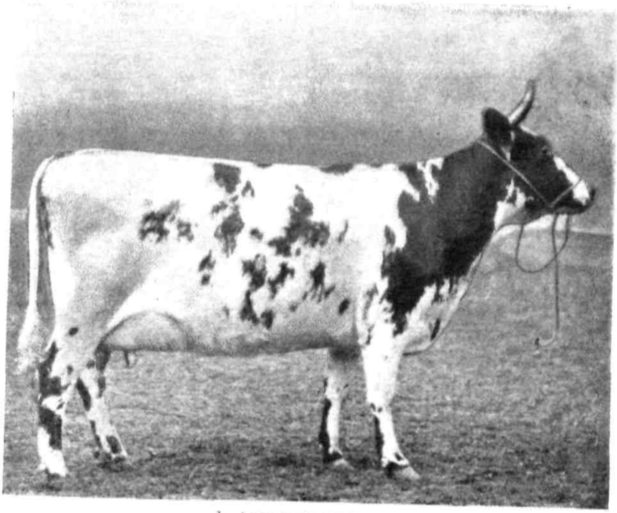
Number of cows tested.	Days in milk.	Yields per day. Milk.	Yields per day. Butter.	Ratio.
2,902	106	32 lb. 14 oz.	1 lb. 12¾ oz.	18·62

Or about 8 quarts of milk required to make 1 lb. of butter.

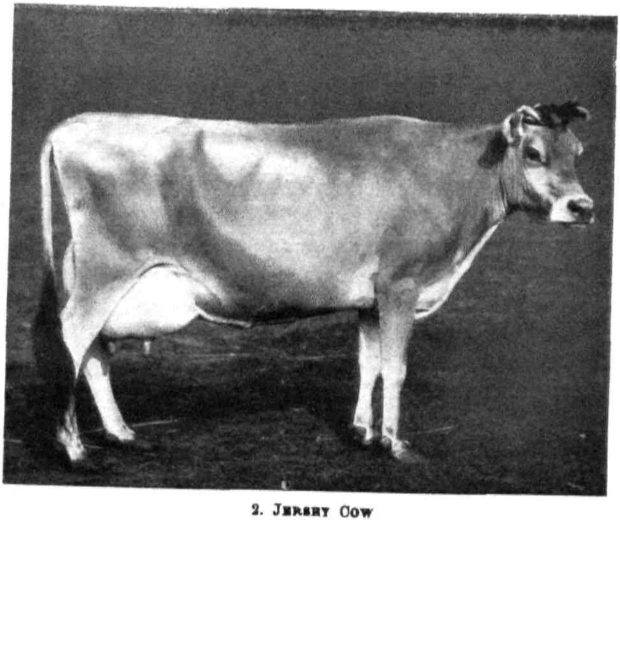
The colours of the Jersey are light and dark fawn, silver-grey and mulberry, mixed occasionally with white. At one time the fashion in England demanded whole or solid coloured animals, but this has practically died out.

The following are the points characteristic of the breed: Head, small and lean; face dished, eyes full and placid; horns neat, well formed, small and convex, well

PLATE IX.

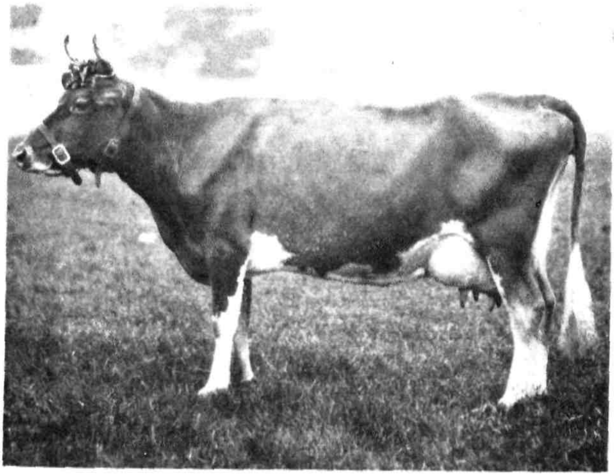


1. Ayrshire Cow

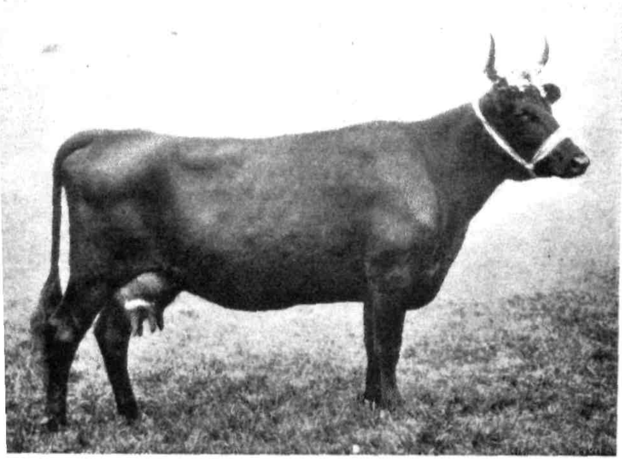


2. Jersey Cow

PLATE IX.—*continued.*



3. Guernsey Cow.



4. Kerry Cow

tinged with yellow; ears small, thin, and yellow inside; neck and throat straight, thin, and clean; back level, and broad at loins; barrel well sprung, deep at flanks; legs short and small, and generally fine in bone throughout; tail long and fine; hide thin, mellow, and of a yellowish tinge; hair soft; udder symmetrical—full forward and behind; teats squarely placed and not too short; milk veins large and long; escutcheon large and full on thigh.

The question of pedigree in Jerseys is peculiarly important to breeders, as the influence of the sire in carrying on the milking proclivities of the breed is most marked.

The cows are gentle and docile, but the bulls, despite their small size, are often fierce.

GUERNSEY (Plate IX., 3).—The islands of Guernsey, Alderney, Sark, and Herm are the homes of the Guernsey cattle, which are kept pure there by the same kinds of restrictions as are adopted in Jersey for the protection of the native breed of that island. Herds of pure-bred Guernseys exist in the Isle of Wight and in various southern counties of England. They have not the refined and elegant appearance of the Jerseys, but they exceed the latter in size. They are usually of a shade of fawn, with or without white markings, whilst in some cases their colour almost merits the appellation of 'orange and lemon.' The nose is cream-coloured and free from black markings, whereas in the Jerseys there is a dark muzzle, encircled by a light colour, thus giving a 'mealy-mouthed' appearance. Points taken to indicate the colour of the milk (or in bull that of offspring): Skin yellow in ear, on end of tail, base of horns, and body generally (also udder and teats in cow); hoofs amber-coloured. The head should be fine and long; the muzzle expanded, with wide nostrils; eyes large and gentle; forehead broad; horns yellow at base, curved, and not coarse. The neck should be long (thin in the cow and masculine in the bull), and the throat clean. The back should be level to root of tail, broad and level across loins and hip, running long; thighs long and thin; tail fine, and reaching to hocks,

Dexter heifer and her female progeny during thirty-four years, afterwards followed by the mating of the male and female progeny.

Dexters are shown not only for beef at the Smithfield Show, but also in the dairy trials at the Royal Agricultural Society's shows. At the meeting at Liverpool, 1910, three Dexters yielded in twenty-four hours an average of 35 lb. 4 oz. of milk, forty-three days after calving.

FEEDING AND MANAGEMENT OF CATTLE

There are three methods of **rearing calves**:—

(1) The first, the oldest method—still followed in the case of valuable pedigree stock—is to let the calf run with its dam during the first season, and derive its nourishment direct from the udder of the cow.

(2) The method common in the North of England, where the calf is removed at birth and hand-fed for the first week on the mother's milk given warm. For the next week or so new milk is continued, not necessarily the mother's, and then separated milk is gradually introduced until the diet consists of separated milk only made up to the standard of whole milk with some substitute.

(3) The method usually followed in the South, the calf being allowed to suck the cow for the first week or so, and then gradually being put on to a diet of separated milk, made up with some substitute as above.

On farms where no separated or skimmed milk is available, gruel made from calf-meals (either purchased or compounded at home) have to be depended upon entirely for rearing calves. In these cases a limited quantity of new milk is generally used for the first few weeks.

Male calves are either destined to be sold off young to the butcher, to be killed for veal; or, in the case of bullocks, they are generously fed in the stall, in order to produce beef at as early an age as possible; or, again, the best of them are kept for breeding purposes.

When cows are allowed to suckle their calves, it is convenient, if it can be arranged, for the latter to be

dropped early in the year, and a heifer should give birth to her first calf in April or May. Each year's calf then comes a little earlier than the preceding one, so that when at full profit, at about the third or fifth calf, the cows are flush of milk at the time it fetches most money —namely, in winter.

Calves born late in the year rarely do so well as those born earlier. The best calves are those born in January and February, for these become strong enough to turn out during summer. Some breeders, however, prefer to keep calves under cover until they are a year old.

When the calf is taken away from the dam, numerous methods, as stated above, are resorted to by different breeders. In some cases the calf is removed at its birth, in others it is allowed to remain with the cow from a few days up to a period of some weeks.

The object in view is an ingenious one. It is to still feed the calf upon cow's milk, but milk from which the natural butter-fat has been removed, and a cheaper kind of fat, or some equivalent carbonaceous material, substituted for it. Although it is cheaper, it does not follow that the substitute is any the less valuable as a constituent of the food of the calf, yet the farmer secures, for his own purposes, the butter with its relatively high commercial value. Skim-milk, whether obtained by the old system of setting the whole milk, or by the newer method of passing it through a separator, contains practically all the valuable nitrogenous, saccharine, and mineral matters of fresh milk: it has simply lost the fat. When skim-milk is used for feeding calves, boiled linseed is an excellent material to mix with it in order to take the place of the cream that has been removed.

Other substances which have been used of recent years as **cream equivalents** with a fair amount of success are:—

(1) Cod liver oil; the amount used being 2 oz. per day, carefully stirred into the separated milk.

(2) Pure linseed cake; being first finely ground, and then steeped in hot water from 8 to 10 hours.

(3) Mixed meal consisting of equal parts by weight of

oatmeal, maize meal, and pure linseed, steeped in boiling water and made into gruel.

A young calf requires at first about three quarts of new milk daily, gradually increasing to six quarts, and it should get this in equal portions at regular intervals. It should be kept as quiet and undisturbed as possible, as this will hasten growth.

Considerable patience and some skill are required in teaching a young calf to drink. When the little creature has fasted for some hours, the first and second fingers of the right hand are extended before the calf, which at once seizes them and commences sucking. A pail of lukewarm milk being held in the left hand, the right hand is gradually lowered till the calf's lips enter the milk, which the young one sucks up, care being taken to keep its nostrils clear of the liquid. After a few lessons the pupil becomes proficient, and is stimulated to persevere by hunger.

As growth progresses and strength increases, small wisps of hay are offered to the calf; these it first sucks, then nibbles, and finally eats. Chopped turnips or carrots, with sweet hay, follow, and when the calf is able to dispose of these a further advance may be made to linseed and crushed oats.

In the **calf-feeding trials** recently conducted by the Irish Department of Agriculture at the Cork Exhibition, the ration fed to calves after a month old which gave the best results was as follows, viz. :—

6 quarts of separated milk.
½ lb. linseed cake.
½ lb. calf meal (consisting of equal parts by weight of oatmeal, maizemeal and pure linseed).

This ration cost 1*s.* 6¼*d.* per week, and the average gain in live weight per calf during the same period was 12½ lb.

Production of Beef.—Calves intended to be ripened off as beef at about two years old or less are kept in a constantly progressive state, and are never allowed to lose their 'calf flesh,' as such loss would have to be made good before any further growth could take place.

At four to six months old the supply of milk is stopped, linseed cake and oatmeal being correspondingly increased. Animals cake-fed in this way under cover produce much valuable manure.

Where beef cattle are not intended to go to the butcher so soon, the yearling calves graze clover 'seeds,' or pastures, through the summer, in some cases receiving at the same time a daily allowance of up to 3 lb. of cake or meal per head. If, however, they are on good pasture they do not get cake, which is only given during the season in which they are fattened off. Early in autumn they are transferred to yards, and fed upon straw or hay, with a supply of roots, and 3 lb. or 4 lb. of cake or meal, this being gradually increased up to 10 lb. or 12 lb. per head per day, the young beasts going to the butcher at from two years to two and a half years old.

On many grass-land farms cattle are not bred but only fattened. They are bought in as store cattle about April or May, when the pastures begin to grow, and are sold off fat in the course of the summer and autumn. Land of first-class quality will fatten one beast per acre without any additional food. It is, however, becoming more the custom to give artificial food, especially cake, as both the animal and the pasture are benefited thereby. Hitherto store cattle have been usually bought in, and fat cattle sold off, by guesswork, the contracting parties relying upon the keenness of their sense of sight and touch. Owing to the unreliable results of such a system of dealing, the weighing machine for cattle is coming more into use.

Winter Fattening of Cattle (*see chap.* xxvii., p. 543).—The following may be taken as an average estimate of the quantity of food consumed, and the return which may be expected when feeding two or three year old bullocks in winter during the last four months.

The amount of roots consumed (principally swedes) will vary from some 60 up to 112 lbs. per day; the larger quantity being used by North Country feeders and the smaller in the South.

The amount of cake and meal used will generally average some 8 lb. per day, starting with 4 to 6 lb., and increasing, say, 2 lb. per month up to 10 to 12 lb. More cake is used in the South, as a rule, than in the North.

The quantity of hay and straw used as fodder will vary according to circumstances, but together they should amount to some 20 lb. per day.

Calculation of Cost of Feeding Bullocks per Week.

	Per day.	Per week.	Cost per cwt.	Cost per week.	s.	d.
Roots ..	80 lb.	5 cwt.	3d. (consuming value)	=	1	3
Cake ...	4 „	28 lb.	7s.	=	3	6
Meal ...	4 „	28 „				
Hay ...	8 „	56 „	2s. (consuming value)	=	1	0
Cost of producing 14 lb. of beef				=	5	9

The value of the manure produced is considered as a set-off against the straw consumed (as fodder and litter) and the labour.

The live-weight increase of large bullocks, as above, during the latter stages of fattening, may be taken at an average of 20 lb. per week, and allowing the proportion of dressed carcase to fatted live-weight (during the final stages) at 70 per cent., this represents an increase of some 14 lb. of dressed beef per week. A gain of 2 to 3 lb. live-weight per day during a feeding period of 16 to 20 weeks may be considered as good.

CHAPTER XXV.

SHEEP: THEIR BREEDS, FEEDING, AND MANAGEMENT

The chief native breeds of sheep recognized in this country include:—

Leicester	Suffolk	Lonk
Border Leicester	Cheviot	Dartmoor
Cotswold	Black-face Mountain	Exmoor
Lincoln	Herdwick	Welsh Mountain
Kentish, or Romney Marsh	Ryeland	Derbyshire Gritstone
Oxford Down	Devon Longwool	Limestone
Southdown	South Devon (or Hams)	Wensleydale
Shropshire	Dorset Horn	Kerry Hill
Hampshire Down		Clun Forest
		Roscommon

The Border Leicester, Cheviot, and Black-face Mountain breeds may be assigned to Scotland, the Welsh Mountain and Kerry Hill breeds belong to Wales, and the Roscommon breed to Ireland. All the others are English.

These breeds may be further grouped as longwool breeds, shortwool breeds, and mountain breeds.

The *longwool* breeds are the Leicester, Border Leicester, Cotswold, Lincoln, Kentish, Devon Longwool, South Devon, Wensleydale, and Roscommon.

The *shortwool* breeds are the Oxford Down, Southdown, Shropshire, Hampshire Down, Suffolk, Ryeland, Dorset Horn, and Clun Forest.

The *mountain* breeds include the Cheviot, Black-face Mountain, Herdwick, Lonk, Exmoor, Welsh Mountain, and Limestone.

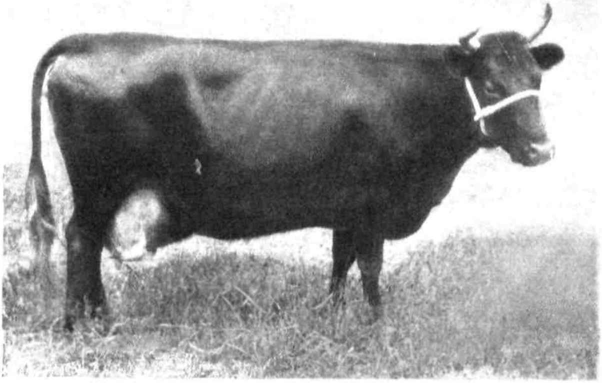
The true mountain breeds are all *horned*—usually the males only in the case of the Cheviot, the Herdwick, and the Welsh breed. The only other horned breed is the Dorset, in which both sexes are furnished with horns. All the remaining breeds are polled, or *hornless*, though there is a tendency amongst certain breeds, such as the Hampshire and the Shropshire, to develop horns, which are only kept down by means of selection

As regards colour, the Leicester, Border Leicester, Lincoln, Kentish, Cheviot, Ryeland, Devon Longwool, South Devon, Dorset Horn, Dartmoor, Exmoor, and Roscommon are white-faced breeds. The Hampshire and Suffolk are black-faced breeds, whilst the Blackface Mountain and the Lonk have more or less distinct black colour upon the face.

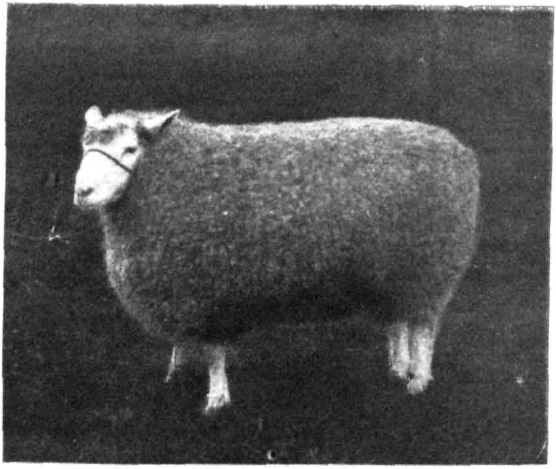
LEICESTER (Plate X., 2).—This is the breed of sheep that Robert Bakewell, of Dishley, improved by his judgment and skill. Leicesters are the oldest pure breed of sheep, and have been used in the improvement by crossing of many other breeds. *The Times*, in its agricultural columns, in 1909, referred to the Leicester as 'that grand old Dishley breed.' The flocks are established chiefly in Yorkshire (East and North Ridings), Durham, Cumberland, Westmorland, Lancashire, and Leicestershire. The Leicester has been wonderfully improved of late years, and is now produced in regard to scale and bone almost equal to the Lincoln; and it is noteworthy that at the Smithfield Club Show in 1907 Leicesters were awarded the championship for longwools of any breed. A Bradford specialist has stated that the Leicester-Merino cross produces the champion crossbred clip of the world.

The following is the official description of the English Leicester: Lips and nostrils black; nose slightly narrow and Roman, but the general form of the face is wedge-shaped, and it is covered with short white hairs; forehead covered with wool; no vestige of horns; blue ears (sometimes white), thin, long, and mobile, a black speck on face and ears not uncommon; a good eye; neck short and level with back, thick, and tapering from skull to bosom; breast deep, wide, and prominent; shoulders somewhat upright and wide over the tops; great thickness from blade to blade, or through the heart; well filled up behind the shoulders, giving a great girth; well sprung ribs, wide loins, level hips, straight and long quarters; tail well set on, good legs of mutton, great depth of carcase, fine bone, a fine curly lustrous fleece (the sheep are well-woolled all over) free from black hairs, with firm flesh, springy pelt, and pink skin.

PLATE X.

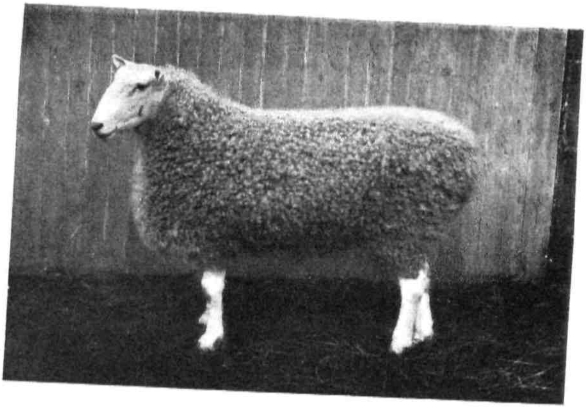


1. Dexter Heifer.



2. Leicester Shearling Ram.

PLATE X.—*continued.*



3. BORDER LEICESTER RAM.

4. COTSWOLD RAM.

The general form of the carcase is square or rectangular; legs well set on, straight hocks, good pasterns, and neat feet.

BORDER LEICESTER (Plate X., 3).—These sheep have held a prominent place for the purpose of crossing with slower fattening breeds, such as the Cheviot and Scotch Mountain Black-face, the produce of which by the Border Leicester ram gives a cross difficult to equal for early maturity and quality of mutton. George and Matthew Culley, students of Robert Bakewell, of Dishley, brought his improved Leicesters to Northumberland (about 1767), from which they spread into other Border counties. They did not receive the distinctive name of Border Leicesters until about 1869. The characters of the breed are as follows: Sharp profile, dark full nostril, bold eye, head high set on a regular tapering neck. A ram at about 18 months old stands about 32 inches in height at the shoulder, with wide level back well covered with firm flesh, wide well-sprung ribs, flat and wide loin, and light offal, enabling easy and graceful movements. Border Leicesters mature quickly and fatten early, producing in under a year a dressed carcase of 80 lb. and a good-combing fleece of 10 to 15 lb.

COTSWOLD (Plate X., 4).—This large and handsome Gloucestershire breed can definitely be traced back to the early part of the fourteenth century, and it has played an important part in the history of the English wool trade. Over a century ago it was much improved by the introduction of Leicester blood. The points of the modern breed are as follows: The head should be wide between the eyes, and the eye itself full, dark, and prominent, but not coarse about the brow. The face should be wide in proportion to the space between the eyes, not too flat; nostrils well expanded, and the nose dark in colour. The head should be of moderate length, with a well-marked tuft of wool on the forehead. The neck should be large and muscular, with a gentle curve enabling the head to be carried well up. The shoulders should lay well back; shoulders and chines well-fleshed. The ribs should be deep and well sprung; hips and loin wide, and well-fleshed. The rump

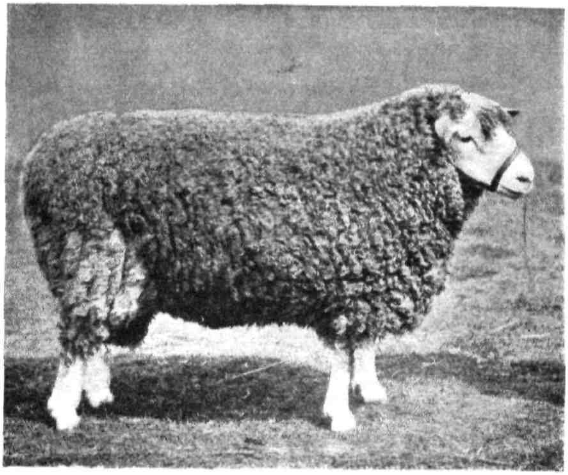
should be level with the back, the leg of mutton well let down to the hock and thick outside. The legs should be straight, of moderate length, and well set apart. The fleece should be thick, long, and lustrous.

The Cotswold mutton, though juicy, is somewhat fat. The breed is valuable for crossing, as it imparts size.

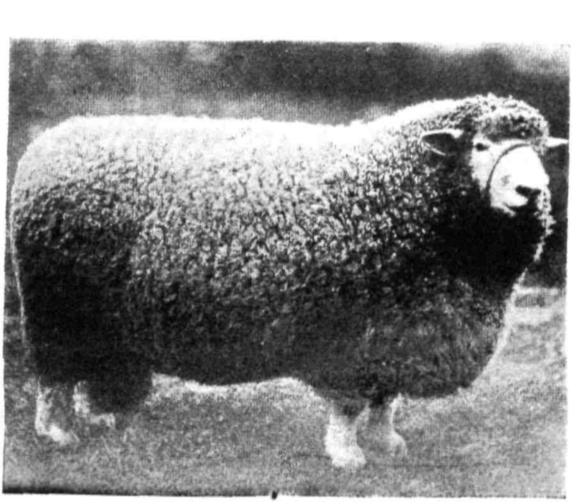
LINCOLN (Plate XI., 1).—These longwoolled white-faced sheep are descended from the old native breed of Lincolnshire, improved by the use of Leicester blood. They are a hardy prolific breed, only rivalled in size by Cotswolds and South Devons. For the production of wool they have no rival among British breeds. The carriage should be good and the form symmetrical. The body should be deep and well-proportioned, with good bone and length; straight wide back, and deep wide breast; hind quarters broad; thighs wide and full, and legs well apart; skin soft and pink-coloured. The head should be covered with wool to the ears; forehead tufted; eyes large, bright, and expressive; ears fairly long, and spotted or mottled. The neck should be of medium length, well set on, and with good muscle. The legs should be broad, well-shaped, woolled to the knees, and white in colour. The fleece should be of even length and quality, not less than 8 inches long for a year's growth; wool long, strong, rather fine, and lustrous, without tendency to become matted.

KENT OR ROMNEY MARSH (Plate XI., 2).—A typical description of the breed is as follows: Head wide, level between ears, with good thick fore-top, no horns nor dark hair on the poll, which should be covered with wool. Face in ewes full and in rams broad and masculine in appearance. Nose in all cases broad and black. Neck well set in at the shoulders, strong and thick. Shoulders wide, well put in, and level with the back. Chest wide and deep. Back straight, with wide and flat loin. Rump wide, long, and well turned. Tail set almost level with the chine. Thighs well let down and developed. Feet large and black. The fleece of even texture, uniform, and of good decided staple. The skin should be of a clean pink colour, and every effort should be made to improve the quality of the breech wool.

PLATE XI.

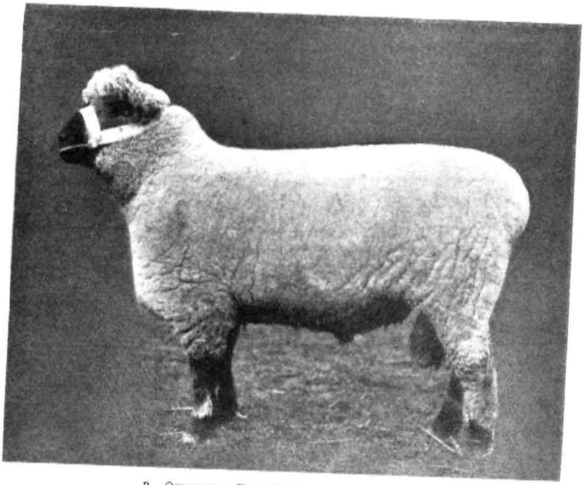


1. LINCOLN TWO-SHEAR RAM.

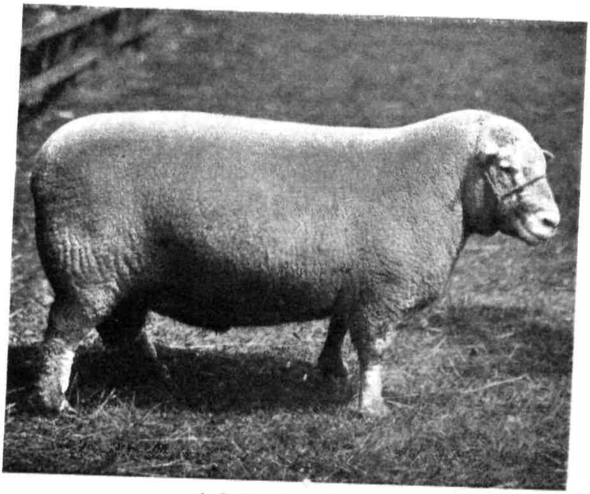


2. ROMNEY MARSH RAM.

PLATE XI.—*continued.*



3 OXFORD DOWN SHEARLING RAM.



4. SOUTHDOWN RAM.

The breed is much appreciated in its native district and equally so in the continually extending area in the Colonies and abroad, to which this breed is being exported yearly in increasing numbers. Its hardiness enables it to withstand the extremes of climatic changes with indifference. Bred as it has been for generations upon the exposed marshes, Nature has during this period gradually but surely left none but those with vigorous and sound constitutions. None others could successfully thrive in the conditions under which it is generally kept.

The same testimony is vouched for by its breeders in North America, Australasia, Tierra del Fuego, the Falkland Islands, Punta Arenas, Chili, and the Argentine.

It has great adaptability and thrives upon rich and poor pasture. In its native district times of abundance and times of scarcity are experienced, and the reason why the breed has been able to acquire the characteristic referred to is because it has no variation in its food, like many other breeds, being on grassland the whole year.

In lambing time there is no need of costly shelter. They breed lambs in the open, and the dams take care of their lambs. Natural treatment such as this breed generally gets has given it this valuable trait of being able to take care of and protect its young without artificial aid. Probably the most desirable characteristic of the breed from the grazier's point of view, and also from that of Colonial and foreign export buyers, is that they do not flock together and taint their land, but feed and graze singly.

The wool is demi-lustre, and has become very much more valuable in recent years by reason of the closer attention given it by those who are interested in the improvement of its fleece; in fact, the fleeces of the Romney Marsh sheep at the present time are becoming much nearer perfection than at any previous period. Its flesh is excellent, when grazed and fed on marshland only. It feeds rapidly and produces mutton of high quality, with great depth of lean flesh and small proportion of fat. Its freedom from fluke and other

infectious diseases is notable; so high, indeed, is the reputation of the breed in this respect in Australia and New Zealand that it is termed practically fluke-proof.

Oxford Down (Plate XI., 3).—This breed has been gradually built up since 1820 by crossing shortwool Hampshire and Southdown ewes with longwool Cotswold rams. Although the forelock of the latter has been inherited, Oxford Downs approximate more nearly to the shortwool type, and are classified as such. Twyman, of Whitchurch, Hants, was the first to establish the breed. Characters as follows: Bold masculine head, well set on strong neck; poll well covered with wool. Face uniform dark colour, black being preferred; ears of good length; shoulder broad; breast broad and well forward; back full and level; ribs well-sprung; barrel deep, thick, and long, with straight underline; legs short and dark-coloured, standing square and well apart. Entire body covered with wool of close texture, good length, fine quality, and without curl. Mutton firm, lean, and of excellent quality.

Oxford Downs are hardy sheep, maturing early, and noted for their excellent all-round qualities. Fat lambs three to four months old, often yield dressed carcases weighing 40 to 50 lb., while many are sold for mutton when nine months old, and give dressed carcases of 80 lb. They are the heaviest of all the Down breeds, and second heaviest of all British breeds. They thrive equally well on both arable and pasture land and in every climate, and fatten on a comparatively smaller quantity of food than any other breed. Unlike some kinds of sheep, Oxford Downs flourish everywhere, and they are exported to nearly every country in the world. They are great favourites either for keeping as a pure breed or for crossing with other breeds, which they invariably improve.

Southdown (Plate XI., 4).—This short-woolled hornless breed is known to have existed for many ages in its native home on the Southdown Hills, and was noted even a century ago for its hardy constitution and the fine flavour of its mutton. Characters as follows: Head

wide, level between the ears, with no sign of slug or dark poll. Face full, not too long from eyes to nose; of one even mouse colour, not approaching black or speckled; under-jaw light. Eyes large, bright, and prominent. Ears of medium size, and covered with short wool. Neck wide at base, strong and well set on to shoulders, throat clean. Shoulders well set, the top level with the back. Chest wide and deep. Back level, with a wide flat loin. Ribs well sprung, well ribbed up, thick through the heart, with fore and hind flanks fully developed. Rump wide, long, and well turned. Tail large, set on almost level with chine. Legs of mutton (including thighs, which should be full), well let down, with deep, wide twist. Wool of fine texture, great density, and sufficient length of staple, covering the whole body down to hocks and knees, and right up to cheeks, with full foretop, but not round eyes or across bridge of nose. Skin of a delicate bright pink. Legs short, straight, of one even mouse colour, and set on outside the body.

The Southdown is the foundation of all other modern 'Down' breeds, and is especially noted for its production of mutton. Its chief characteristics are a hardy constitution, an adaptability to almost any climate, a habit of thriving on bare pasture, and the generous return which it gives for good feeding, a comparative freedom from lameness, a general aptitude to improve other breeds by crossing, a fine quality of mutton and excellence of wool. In wool production Southdowns compare favourably with other breeds, their fleeces being of a fine quality, close, thick, and heavy in proportion to the size of the sheep. The wool realizes the highest price of any native breed of sheep. The Southdown excels as a mutton producer in its quickness of feeding, early maturity, and prime quality.

As the sheep withstand extremes of heat and cold, they are suitable for every climate. Southdowns excel for 'crossing' or 'grading up' purposes, because, being the oldest pure breed of short-woolled sheep, they possess in a marked manner 'prepotency,' or the power of impressing their good characteristics on other breeds. Southdown rams have been used for crossing on nearly

every breed of British sheep, and they have been exported to all parts of the world.

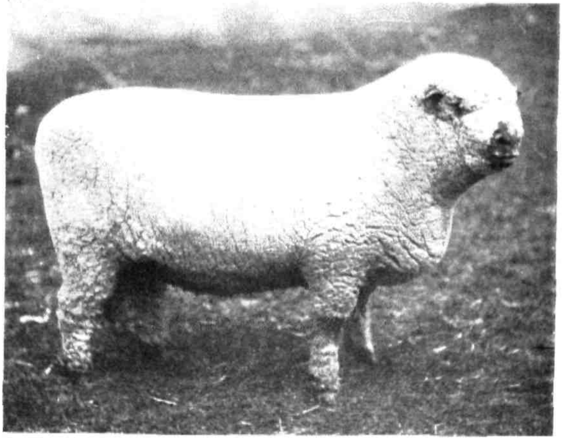
Half-bred Southdown lambs have almost ideally perfect conformation and attract the attention of the experienced buyer more readily than any other cross-bred lamb. The body is square and set close to the ground, the bone is light, and the leg of mutton perfect. Extensive experiments carried out in New South Wales show that crosses with the Southdown produce the best-shaped, best fleshed, and earliest maturing lambs.

SHROPSHIRE (Plate XII., 1).—Though heavier in fleece and bulkier in carcase, the Shropshire sheep has much the appearance of an enlarged Southdown. It was derived from the old native sheep of Shropshire and Staffordshire, an infusion of Southdown blood having aided in its improvement. The progress and development of the breed have been remarkably rapid, and it is extending in all directions. Points: As distinguished from the Southdown, the Shropshire has a darker face, soft black as a rule, with very neat ears, whilst its head is more massive, and is better covered with wool on the top; legs short and black in colour; back lean and fleshy; legs of mutton deep and full; skin a bright cherry colour.

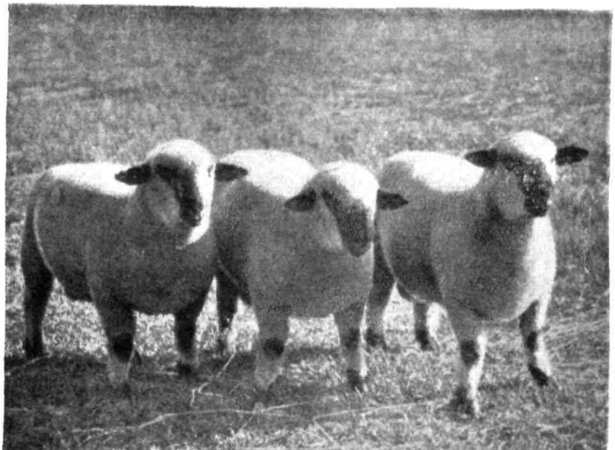
Shropshires are very prolific, 150 to 175 lambs per 100 ewes being the usual average. The ewes are excellent mothers, and yield a large amount of milk. The fleece is very heavy and of good staple, fine in texture, and very dense; there is little loss in scouring. The breed matures early. If well cared for, with relatively moderate consumption of food, the wethers are fit for the butcher at ten to twelve months old. As fat lambs they mature very early, as also do Shropshire crosses. The mutton is rich in flavour, close-grained, and juicy, with a large percentage of lean. Great hardiness, sound constitution, aptitude for making the best of available food, and great adaptability to various soils and climates are notable characteristics. Shropshires are found to thrive well in all parts of the world.

HAMPSHIRE DOWN (Plate XII., 2).—Early in the nineteenth century the old Wiltshire Horned Sheep and the

PLATE XII.



1. Shropshire Two-Shear Ram.



2. Hampshire Down Ram Lambs.

Suffolk sheep excel in the production of fine lean mutton, and hold an unequalled record in the annual carcase competitions, open to all breeds at the Smithfield Club Show, London. Their proclivity for early maturity is highly developed. Ram lambs are so large and well developed that for breeding purposes they are largely used in preference to older sheep. As regards fecundity, 150 lambs reared per 100 ewes is a frequent average. Suffolks possess a very hardy constitution, and, as they have not been pampered, they will, if necessary, find a living on bare pasture, where many breeds would starve, and they can be driven long distances without suffering. Suffolk rams are also much in demand for crossing purposes. Crossed with the longwool breeds, they produce a fine carcase of lean meat, a heavy fleece of good quality, and increase the productive and milking qualities.

CHEVIOT (Plate XII., 4).—These white-faced sheep are native to the Cheviot Hills, and though they have spread over most of Scotland and a good deal of England, still thrive best on grassy uplands, thus differing from Black-faces, which do best on coarser, mossier land. For symmetry they are unequalled, being probably the most beautiful of all breeds; ewes hornless, rams generally so, though inclined to develop scurs or short horns, and sometimes come with horns. The withers are sharp. The carriage should be lively, with plenty of action, and the eye bright. The head should be of medium length, well covered with short, fine, white hair; ears nicely rounded, erect and not too long; nose arched and broad, with full and widely open black nostrils; neck strong, but not too long; ribs well sprung, and carried well back towards the hock-bones; tail well hung and nicely fringed with wool; legs broad and flat, covered with short, hard, white hair.

Cheviots come next to Black-faces in their ability to subsist on the scantiest fare; they can live through the severest winters without any artificial food, though when there is any depth of snow a little hay should be given. The mutton is the best produced, being generally quoted ½d. per lb. higher than any other in the market.

and Cheviots divide with Suffolks the honour of winning more carcase competitions at Smithfield than all the other breeds put together. The wether lambs are mostly fed off at from 10 to 18 months old, when their carcases yield 40 to 60 lb. of mutton. The ewes are sold at five or six years old to Lowland farmers, who breed from them by the Border Leicester ram the far-famed 'half-bred' sheep.

The wool is of medium quality and fineness, and the fleeces average about 4½ lb. each. From Cheviot wool the famous Scotch tweeds are made, and though Colonial wools are now often employed in its manufacture, cloth made from the pure Cheviot far outwears all others.

Black-face Mountain (Plate XIII., 1).—It is doubtful where this breed has its origin, but it is certainly now the most important, so far as numbers go, in the British Isles. It occupies almost exclusively all the higher grazings of Scotland (which have not been cleared for deer), and is found in large numbers in the counties of Northumberland, Cumberland, Yorkshire, Lancashire, and in many parts of Ireland. The chief characteristics of the sheep are their great hardiness and the fine quality of the mutton they produce.

The face and legs should be black or mottled, free from dun or brown, smooth, and glossy. Wool should not appear among the hair. The nose should be strong, broad, and prominent, with wide black nostrils. The horns of the ram should be large, not joined at the base, but springing level from the crown, and its spirals should hide the short ears. The tail only reaches to the hocks, and it is therefore not necessary to dock it.

The wool is a unique product, and is now almost entirely used by the carpet trade, the great bulk going to America. The fleece weighs, on an average, 3½ to 4½ lb. for ewes, and from 5½ to 6½ lb. for three-year-old wethers. It is wavy, loose, and strong, but should be as free as possible from kemp and blue spots. The rams command high prices at the autumn sales.

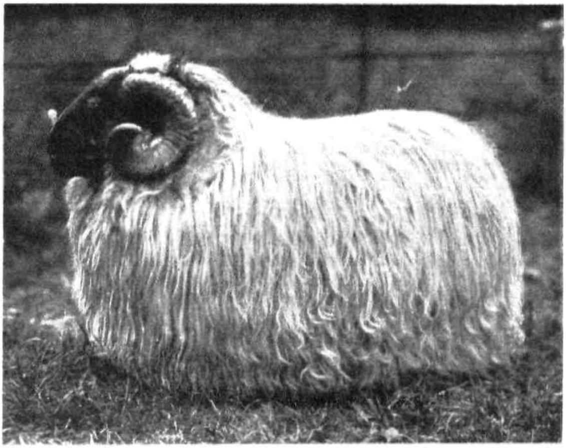
Herdwick.— This extremely hardy breed thrives upon the poor mountain land in Cumberland, Westmorland, and North Lancashire. The rams sometimes have curved

horns, but the ewes are hornless. The colour of these sheep is white, with a few darkish spots here and there; the face may be either white or light grey in adults. The head and neck should rise well from the shoulders, and be carried gaily. The withers are usually sharp. The walk should be free, and the body square on the legs during movement. Good coat and good bone are the two most essential characters. The wool is strong, coarse, and open, and inclined to be hairy about the neck. The forehead has a small top-knot, and the tail is broad and bushy.

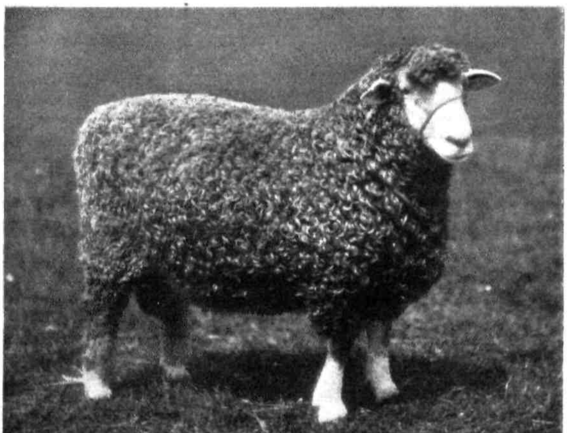
RYELAND.—Youatt (1837) speaks of the Ryeland as being one of the hardiest and most valuable of our English breeds. In writing of the sheep bred in Herefordshire, he says that its distinguishing breed is the Ryeland, so called from a district in the southern part of the county, in which a great quantity of rye used to be grown, and where many of these sheep were bred. He then says that the Ryeland has that form which at once bespeaks it to be patient of hunger and capable of thriving on very scanty fare. It scarcely admits of dispute that the old Ryeland would endure privation of food better than any other breed. Sir Joseph Banks, who was well acquainted with their constitution and habits, used to say that the Ryeland deserved 'a niche in the Temple of Famine.'

The Ryeland of the present day retains to a great extent the hardy constitution of its progenitors; at the same time it is enlarged in size, and its wool-cutting properties have been much increased. The breed, which is generally very symmetrical, has face and legs of a dull white colour (as distinguished from the china-white of the Cheviot and the Cardie). The fleece is closely set on the skin and is of a deep staple; the wool well covering the body in every part, coming well up to the cheeks and ears and covering the top of the head. According to Youatt, Ryeland wool in the early part of the last century was much the finest produced by any British breed, excelling even the Southdown in fineness of fibre and in the number of its serrations to the inch. In recent years the wool has taken a very leading posi-

PLATE XIII.

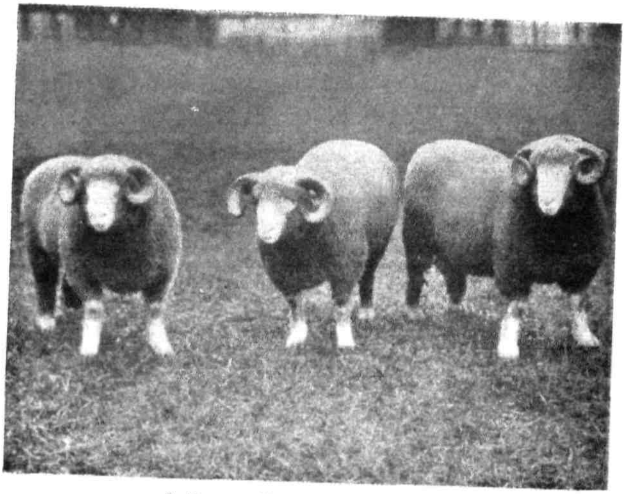


1. Black-Face Mountain Ram.

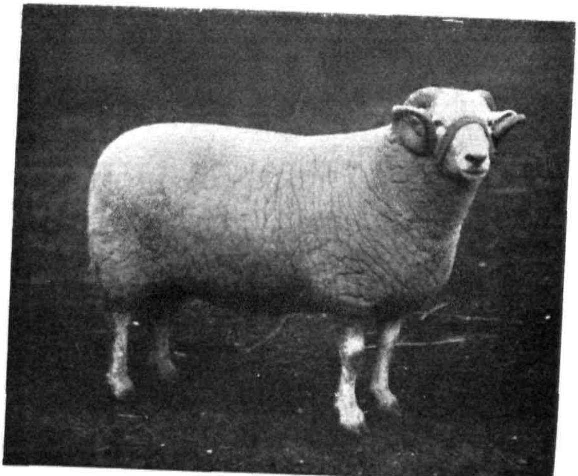


2. South Devon Ram.

PLATE XIII.—*continued.*



3. Dorset Horn Ram Lambs.



4. Welsh Ram.

tion in competition with other breeds at the shows of the Royal Agricultural Society.

The mutton is of fine quality, and the weights of yearling sheep vary (according to management and feeding) from 15 lb. to 20 lb. per quarter, and their fleeces from 6 lb. to 8 lb. per head.

The Ryeland ram is much in favour as a sire of fat lambs, and the sheep generally are noted for thriving on cold damp soils (producing inferior herbage), where many other breeds would starve.

Devon Longwool.—This is a white-faced breed locally developed in the valleys of West Somerset, North and East Devon, and parts of Cornwall. It originated in a strong infusion of Leicester blood amongst the old Bampton stock in Devonshire. The long-woolled fleece is of excellent quality.

South Devon (Plate XIII., 2).—The description of a typical South Devon sheep is as follows: 'The head is broad and rather long, well covered on upper portion with wool; nostrils open and of dark colour, muzzle broad; ears fairly long, of medium thickness, covered with hair, often spotted; neck strong, of medium length; back straight and level from withers to setting on of tail; shoulders flat and well covered; ribs well sprung; loin wide; chest deep and full; tail thick and big; legs straight, squarely placed, well on outside; hind quarters deep and square; skin mellow and of pink colour; fleece dense and even, with great length of staple, curly, and free from kemp and hair.'

This has been for generations a breed covering South Devon and practically the whole of Cornwall. The practice throughout the districts in which we find this breed is for the owner to be his own shepherd. Except at rather rare intervals, such as when one of the larger shows was held in Devon or Cornwall, the outside breeders, other than those resident in the county had but rare opportunities to see the breed.

The establishment of the Breed Society seven or eight years back (which, by the by, is representative of upwards of 200 flocks at the present time), largely altered this, for since that date exhibits have been found at

the Royal Agricultural Show as far away as Liverpool, and the Bath and West of England as far away as Rochester, in Kent, and specimens have also been exhibited at Smithfield, at which show a pen of wether lambs gave the highest daily average gain of any breed at the 1909 show.

This wider exhibition of the breed has resulted in specimens being shipped to Australia, South Africa, Argentina, etc.

There are few breeds equal to it for production of weight and depth of lean flesh, none that excel it in respect to early maturity when given the fullest opportunity for development. It has a heavy, good fleece of wool, full of that curl or crinkle that so many wool users admire and appreciate. Its characteristic appearance is well depicted by the photograph of the ram that is given as a specimen of the breed, the evenness of the fleece of the ram is indicative of the superiority, quality, and evenness of fleece that careful selection can produce. The breed in its own district is termed a 'rent payer,' and those who have tested its value in respect to cross-breeding, particularly upon the Dartmoor and the Down breeds, have found it a very valuable cross indeed.

Dorset Horn (Plate XIII., 3).—This breed has been naturalized in the county of Dorset from time immemorial. It is mentioned in Lisle's 'Observations in Husbandry,' published in 1757, and embodying observations made from 1693 onwards, as possessing great fecundity, a character by which they are still distinguished, as they produce from 130 to 180 per cent. of lambs. The ewes will receive the male as early as April or May, so that the lambs are born in September or October, and ready for the butcher by Christmas. During the last few decades they have been greatly improved, and have supplanted Down sheep in many places. Points of improved breed: Body straight and deep, ribs well arched, loin broad, neck well set on, shoulders full, without coarseness, hind-limb well set down towards the shank, forming a good leg of mutton with small bone. General features pleasing, head stand-

ing well up, horns thin with a symmetrical curl, eye quick and lively, face rather long and thin, lips and nose pink or flesh-coloured.

Dorset Horns are hardy, and do well on most lands. They are excellent nurses, good folding sheep, are noted for early maturity, and yield well-flavoured mutton. The wool commands high prices, and is noted for its whiteness and fine point. Lambs yield from 2½ to 3 lb., ewes from 5 to 7 lb., and yearling rams from 10 to 14 lb. Although the chief home of the breed is South and West Dorset and the Isle of Purbeck, it also commands much attention in other counties of the United Kingdom, as well as in North America, Australia, and New Zealand.

Lonk.—These sheep are found chiefly in N.E. Lancashire and S.W. Yorkshire, deriving their name of Lank or Lonk from the former county. Lonks do admirably well in the districts mentioned, for, being hardy and close-coated, they can withstand the weather.

They are of the horned class, and have been in the country for several generations. A pure-bred Lonk sheep should have a black and white or speckled (to use a local term) face and legs, with a little more black than white. The rams should have large horns, which project well out from the face and turn once or twice round, according to their age, well apart at the roots, not too high, and set upon a good heavy head; nose (Roman) well sprung, and jaw deep, giving, on the whole, a bold appearance; a long, straight, broad back, wide loins and shoulders, well-sprung ribs, and strong bushy tail, reaching to the ground. The legs should be well set on, wide apart, and short jointed.

Considering his size and weight, the Lonk is a neat sheep and nimble walker. A good ram may weigh as much as 200 lb. The fleece should be short and close, not too soft to the touch, filling the hand well, and not of the strong hairy kind. It ought to grow very evenly over the body, with a tuft on the forehead. A good ram fleece will weigh about 12 lb. The breeding ewes are not quite so large as the rams, more compact in body, and having more slender horns, which are not turned

as much as those of the ram. They are good breeders, often rearing two or sometimes three lambs each season. The wethers and young ewes which have not had lambs, are kept for their wool and mutton. They are good grazers, living mostly on the moors. After the first season they will weigh from 80 to 100 lb. dead weight, and are considered the finest mutton we have, there being such a small proportion of fat to the lean.

DARTMOOR.—This ancient hornless breed is practically restricted to the district from which its name is taken. It is the largest kind of native hill sheep, and owes some of its qualities to an infusion of Leicester blood. Dark markings in the face and legs are considered desirable. The head should be large and well formed, the ears of good size, set on level, and covered both inside and out with hard hair marked with black spots. The wool should be long, strong, very fine, and even in quality. It extends on to the poll (which possesses a forelock) and well down on to the legs. The skin should be clear pink. The mutton is of excellent quality.

EXMOOR.—The Exmoor Horn or Porlock moorland sheep are probably direct descendants of the old forest or mountain breeds of England. They have white legs and faces and black nostrils, and are horned, the horns curling more closely to the head than in the Dorsets. The wool is short and the fleece is close and fine. They are delicately formed about the head and neck, but the carcase is narrow. They are exceedingly hardy, and yield finely flavoured mutton.

WELSH MOUNTAIN (Plate XIII., 4).—On the Welsh hills this hardy, active breed has probably remained unaltered for centuries, but its size has been increased in the lowlands by infusions of Leicester, Lincoln, and Down blood. The face and legs are yellow; the rams possess curled horns, while the ewes are generally hornless. The body is narrow, descending towards the shoulder; the tail long, strong, and bushy. The wool is white, short, fine, and thick. The mutton is lean, and of excellent quality.

DERBYSHIRE GRITSTONE.—This breed is one of great antiquity, and there is plenty of existing proof of it.

having bred without the introduction of outside blood for considerably over 150 years. Its origin is lost in obscurity. Latterly a considerable amount of alien blood (Lonk, Limestone, and Scotch Blackface) has been introduced, but still the Gritstone character in such crosses always strongly predominates, thus proving that the sheep must have for many generations been bred pure, or otherwise their characteristics would have entirely or almost disappeared in recent times. The 'home' of the breed is, as the name implies, on the hills of North Derbyshire, but they or their crosses are to be found on the borders of Staffordshire, Cheshire, Yorkshire, and on the Nottinghamshire side of Derbyshire. They are extremely hardy and stubborn disease resisters. They produce, under natural conditions, good lean mutton of medium weight and prime quality, and quick growing lambs. There is no breed of sheep in Great Britain more profitable to the farmer, butcher, and consumer alike.

The prices actually paid to some breeders for their wool afford an absolute proof of its genuine quality, which is equal to the finest Shropshire, and it is said by Bradford experts to be one of the finest hosiery wools procurable in Great Britain.

Limestone.—This hardy, active, horned breed is almost restricted to the limestone fells of Westmoreland, and is probably an offshoot of the Black-face Mountain. The face, legs, and wool are white in colour. The ewes are very prolific, and, like Dorset Horns, come into season unusually early.

Wensleydale.—The Wensleydale longwool sheep is a large, high-standing, long-sided, firm-fleshed Yorkshire-Leicester breed, with a characteristic deep-blue colour in the skin of the face, legs, and ears, which sometimes extends over the whole body, though the shade is darker on the bare or hairy parts. The dark colour is favoured because of the extensive use of the rams in crossing with Scotch Blackface ewes, as they throw dark grey-faced lambs.

The chief characteristic of the Wensleydale is that

given period. Even the site of hayricks and corn-stacks is often determined with a view to conveniently affording a supply of hay and straw during winter, and especially at lambing time, with as little carting as possible. The shepherd is a very important person on a sheep-breeding farm, and one who thoroughly understands his duties, and can perform them efficiently, is a well-qualified man of sound experience.

In this country the arrangements are so made that the ewes of a breeding flock shall lamb down during the winter. In the Dorset Horn flocks the lambs are dropped as early as October. About Christmas time the Hampshire Downs begin to lamb; later the Oxfords, Southdowns, and Shropshires; whilst it is March, or even early April, before the lambs begin to appear amongst the upland flocks of the North of England and of Scotland. The time when the rams are put to the ewes is, therefore regulated according to the date when the lambs are required.

In the first place, it is well to consider the case of a Down flock upon light arable land, where abundant crops of roots are grown. On such farms the sheep are 'folded' on the land carrying the roots, clover, or other crops upon which the animals feed. A portion of the land is hurdled off, and the outer row of hurdles is advanced day by day, whereby the sheep are compelled to eat off the crop with but little waste, whilst they tread and manure the ground with uniformity.

It is a bad plan, especially in winter, to feed sheep upon turnips exclusively. They are a very watery food, 10 lb. of turnips containing about 9 lb. of water. To get enough solid food from turnips alone, the sheep is compelled to take into its system far more water than it requires. As, moreover, this water has to be raised to the temperature of the body, an enormous waste of animal heat is thereby incurred. Hence, it is proper to supply sheep folded on turnips with hay or some other dry food, the effect of which is to reduce the quantity of water consumed more nearly to the proper ratio, a sheep requiring about two parts of water to one part of dry food.

Preparations for Lambing.—Whilst it is a serious mistake to get ewes into too high a condition—that is, to make them too fat—during the breeding period, yet, as the lambing time approaches, it is advisable to feed them rather more generously. Turnips do not contain much nutritious matter, and are specially poor in nitrogenous substance. Hence, as the ewe has not only to maintain herself, but to supply the requirements of the rapidly growing lamb, to which she will in due course give birth, a small quantity of nitrogenous food such as malt-dust, bran, peas, or cotton-cake, with some hay, should be given during the last month preceding lambing.

In some districts it is the custom to run the ewes on grass-land up to Christmas, bringing them on to the 'roots' when lambing commences. In such cases if hard weather is experienced before the end of the year, a little hay and a few roots may be given on the pasture.

Lambing and Care of Lambs.—The *yeaning* season—that is, the lambing period—is the busiest time of the year with the shepherd, and he generally remains in or near the lambing pen all night. The pen is usually made of hurdles, either around or on the warm side of a stack of straw, which will afford material for litter. Around the inside of the pen small coops or compartments are hurdled off, and in these the newly delivered ewes can be isolated if necessary. Other pens, adjoining the first, are built with hurdles as occasion requires, and into these the ewes and lambs are drafted—perhaps the ram lambs into one, and the ewe lambs into another.

In the lambing pen the ewes should receive some cake and oats, with roots and hay, and, as the lambs are now calling for milk, the feeding of the ewes should continue to be of a generous character. As soon as the lambs are strong enough, they are encouraged to run forward through 'creeps' in the hurdles, and to nibble the young shoots of turnip tops, and eat a little ground linseed-cake, provided for them in small troughs. The young creatures are thus fed *through the ewes*, as well as

directly. A mixture of cake, oats, and beans, amounting to about ¾ lb. per head per day, together with 1 lb. of hay, and whatever green food may be convenient, will suffice to keep the ewes in a free milk-yielding condition. Perhaps there is no food equal to oats for promoting a good flow of milk at lambing time. As spring advances the hay may be discontinued, and the sheep allowed to run upon 'seeds,' or permanent pasture. At the same time, the cake should gradually be withdrawn from the ewes, and given direct to the lambs.

When about three or four months old, the lambs are weaned, and they bleat perseveringly for a day or two on being separated from their mothers. It is well to cull out all the 'scrubby,' unthrifty, or unpromising lambs, and to dispose of them. If the flock is a ram-breeding one, special pains are taken to bring the ram lambs forward in attractive stock condition. Wether lambs—the young males intended for the butcher and not for breeding purposes—are fed upon the best the farm can afford, and fattened off as early as possible. The ewe lambs and stock ewes are not so liberally fed.

The purchased foods which are most in favour are linseed-cake, beans, and peas, all broken, and bran and malt. But a constant succession of crops has to be provided—grass in the early spring, then rye and winter barley, followed by such succulent crops as trifolium, vetches, rape, clover, cabbage, and early turnips, by which time the winter feeding on roots will re-commence. Cake and corn, and sometimes hay, may continue to be given throughout, so that, in this system of producing lamb or mutton, no opportunity is lost of tempting the appetite, and furthering the object in view.

In practice, numerous modifications occur of the method which has been described, but the general principle is the same in all. A forcing diet is given when mutton or lamb is the immediate object, and merely a maintenance diet—save at certain periods—to the section of the flock kept for breeding purposes.

Where open upland pastures are available, hurdles are dispensed with, and the sheep are allowed to

'spread,' the shepherd's dog being then on duty. When roots are given, it is preferable to put them through the turnip-cutter, as, although the cost of labour is incurred, this is probably repaid, for the sheep eat up the slices without waste, and with much less fatigue to themselves. White turnips, however, being specially soft, are commonly fed off in the ground. Hay is usually fed in sheep-cribs or racks, and a lump of rock-salt should always be accessible; the lambs in particular will show their appreciation of it. If water is not otherwise available, it should be supplied in troughs.

CHAPTER XXVI.

PIGS: THEIR BREEDS, FEEDING, AND MANAGEMENT

THE native breeds of Pigs recognized in this country include:—

Large White.	Tamworth.
Middle White.	Large Black.
Small White.	Small Black (Suffolk or Essex).
Berkshire.	Lincoln Curly-coated.

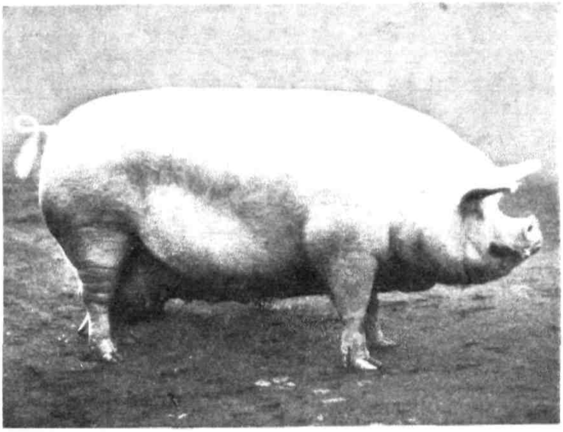
The classification of the breeds of pigs is in a less satisfactory state than that of either cattle or sheep, and in many counties of England there are numbers of swine which could not be fairly grouped under any of the above heads. The Large, Middle, and Small White breeds are, as their name indicates, white in colour; they used all to be included in the term 'Yorkshires.' Lincoln Curly-coated pigs are also white. The Large and the Small Black are named from their colour, while Berkshires are black, with white points. The Tamworth pigs are red.

LARGE WHITE (Plate XIV., 1).—No variety of pigs has made a greater advance in public favour during the

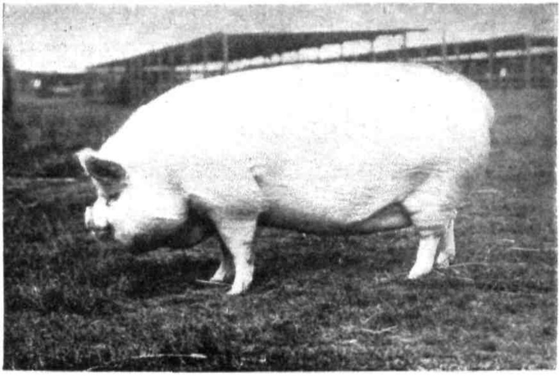
last quarter of a century than the Large White breed. Probably one of the chief reasons for this increased demand has been the extreme suitability of these pigs and crosses between Large White boars and sows of all other varieties for the purpose of the curer of bacon, an article which has become one of the most general breakfast dishes. The white colour which it also impresses so invariably on its produce from sows of any other colour is a valuable asset, as is proved by some bacon curers actually paying a premium on white pigs, since bacon from animals of that colour sells more readily and at a higher price on some of the markets than bacon manufactured from pigs of a dark colour. This, of course, is fancy on the part of the consumer to a certain extent, but it is also an admitted fact that the Large White pigs furnish a larger proportion of lean to fat meat than almost any other breed, so that the consumer who may not be a keen judge of the merits of bacon in an uncooked state has one easy and sure test of the probable leanness of the meat by noticing the colour of its skin. Amongst other advantages possessed by pigs of the Large White breed are their quick growth, their early maturity, and their readiness for slaughter at an early age where small pork is in fashion, or for the production of those very fat and heavy pigs of 300 to 500 lb. dead weight, which are in demand in some parts of the so-called Black Country. The sows, like the boars, are of quiet disposition and very prolific; the sows produce a full flow of milk, which is continued until the piglings are old enough to be weaned. These last are hardy and quick growers, being greatly in demand in those dairying districts where cheese and butter are manufactured for the production of the greatly esteemed dairy-fed pork.

The Large White pig will grow into a large size when fully matured, boars of 10 cwt. and sows of as much as 9 cwt. live weight having been known. They should be long in the head, with ears slightly inclined forward, jowls light but the forehead wide, the neck fairly muscular, the shoulders obliquely placed (so that an appearance of narrowness is given to the shoulder),

PLATE XIV.

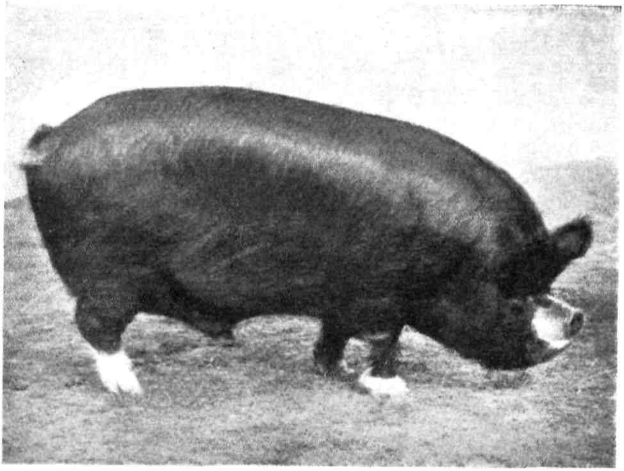


1. Large White Sow.



2. Middle White Sow

PLATE XIV.—*continued.*



3. Berkshire Boar.

4. Tamworth Sow.

the ribs well sprung, the back long, the body deep, with a well-developed flank, the loin muscular, the hind quarters long and wide, and the hams extending quite to the hocks. The legs should be set well outside the body, the ankles firm, the bone fine and hard, the skin firm and thin, the hair plentiful, straight, and of a fine texture.

Middle White (Plate XIV., 2).—The description given above of Large White pigs will apply in most of the particulars to Middle White pigs, save as to extreme size, length of body, and the shape of the head, which is much shorter, with heavier jowls, and smaller and more erect ears. The Middle White pig is also finer in the bone, skin, and hair, and altogether neater in appearance. Although the Middle White boar is preferred for crossing on to the large and coarse sows in some districts for the production of pigs suitable for the manufacture of bacon, and a number of boars of this breed have been exported to Russia, Australia, and some other foreign countries for the same purpose, yet the Middle White is more suitable for the fresh pork trade, whether in the form of London porkers, weighing alive about 100 lb., or in the country where pigs of the weight of 120 to 150 lb. are most in demand. A very large number of pigs suitable for the fresh pork trade are also begotten by Middle White boars from sows of other breeds, particularly those of the Large White and Berkshire breeds. Pigs of the latter cross have been shown of late years at the Smithfield Club shows which nearly approach to perfection in form and quality of fat pigs. Not only so, but these cross Middle Whites and Berkshires mature early, and furnish carcases of fine pork by the consumption of a comparatively small quantity of meal. The cross between Large White and Middle White is probably the best type of pig for farmers' purposes, especially in those districts where heavy fat pigs are more in demand than those of a medium size.

Small White.—These were in great favour some forty years ago, when pork with a much larger proportion of fat to lean meat was in more general demand than at the

present time. These pigs were white in colour. They possessed a heavy covering of hair, were very compact in form, fine in bone, and came early to maturity.

Berkshire (Plate XIV., 3).—These animals are claimed to have been introduced and developed into a distinct breed in West Berkshire, and during the past fifty years most careful attention has been given to their improvement, with the object of producing the best type of animal for the butcher.

The colour of the Berkshire is black, with feet white to about the ankle joint, white tip to tail, and white on the face.

The general conformation should be long, low, level, and deep, straight back, tail set high, head moderate length and dished, wide between the ears, ears fairly erect (not drooping over the face), fringed with hair; ribs well sprung; good length from hip-bone to tail; legs strong, straight, and set square; hair plentiful and fine all over the pig.

They are regular breeders, hardy and most suitable for export, being especially adapted for all climates; not affected by sunburn. Quiet disposition, good mothers, easy feeders, and good foragers; active, and mature very early.

They are now a leading type in all the principal showyards, where distinct classes are given for them, in which the best specimens of the breed may generally be seen to advantage. From a judge's point of view, the first considerations for merit are the desired colour, with fine hair and skin, a shapely head and nicely set ears, and large hams, combined with length and depth of body and quality.

Tamworth (Plate XIV., 4).—This breed is most abundant in the Birmingham district, and is more closely related to the wild boar than the other kinds of native pig, as indicated by its hardiness, active habits, long snout, and comparative leanness of the meat it produces. The old type, however, has been modified by the introduction of Yorkshire blood.

Tamworths should conform to the following standard of excellence: Hair golden-red (free from black), on a

flesh-coloured skin, abundant, long, straight, and fine; head fairly long, snout moderately long and quite straight, face slightly dished, wide between the ears; ears rather large, with fine fringe, carried rigid and inclined slightly forward; neck fairly long and muscular, especially in boar; chest wide and deep; shoulders fine, slanting, and well set; legs strong and shapely, with plenty of bone and well outside body; pasterns strong and sloping; feet strong, and of fair size; back long and straight, loin strong and broad; tail set on high and well tasselled; sides long and deep; ribs well sprung and extending well up to flank; belly deep, with straight under-line; flank full and well let down; quarters long, wide, and straight from hip to tail; hams broad and full, well let down to hocks; action firm and free.

Tamworth crosses are noted for their hardiness.

Large Black (Plate XV., 1).—This is one of the oldest breeds, and there are two original types, one from Devon and Cornwall, the other from Suffolk and Essex. The former are larger and more refined, the latter hardier and more prolific. The good qualities of both strains will no doubt ultimately be fully blended. The Large Blacks can claim to be a utility breed, suited to the needs of the modern breeder, feeder, bacon-curer, and consumer. They were formerly fed to enormous weights, but weight has now given way to greater quality, and the breed yields at a very early age the chief desideratum—viz., a long, deep-sided carcase of 160 to 190 lb., dead weight, light in shoulder, jowl, and offal, and showing a larger proportion of lean meat than any other breed.

Large Blacks are very docile, and the forward carriage of the ears is supposed to conduce to quiet field grazing. The colour is claimed to enable summer pasturing or field feeding without risk of sun-scald. The sows are noted for their fecundity.

Large Blacks should conform to the following standard: Head of medium length, and wide between the ears; ears thin, inclined well over the face, and not extending beyond point of nose; jowl of medium size; neck fairly long and muscular; chest wide and deep; shoulders well-developed, in line with the ribs;

back long and level, and ribs well sprung; loin broad, and sides very deep; quarters long, wide, and not drooping; hams large, and well filled to hocks; tail set high and of moderate size; legs short, straight, flat, and strong; skin fine and soft, with a moderate quantity of straight, silky hair.

SMALL BLACK.—This name is given to local races characteristic of Suffolk and Essex, and much resembling the Small White, except in colour, the possession of scantier hair, and greater length of body and leg. Small Blacks have a small well-formed head and symmetrical figure. They fatten well, yielding a good proportion of lean meat, and mature early.

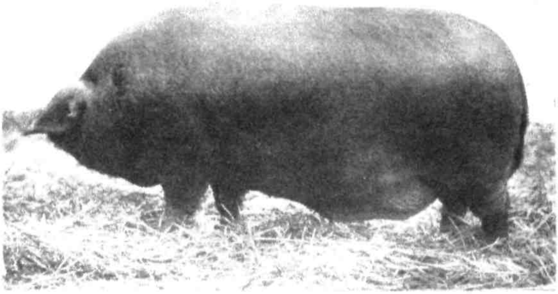
LINCOLN CURLY-COATED (Plate XV., 2).—Until the last few years this ancient breed of large pigs was only well known in East Lincolnshire. The abundant white hair is curly, as the name indicates, and the skin is of the same colour, though some blue spots are usually present. The face is shorter than that of the Large White, and the ears (which should be of moderate length) fall over it, while the nose is straight. It is claimed to be unequalled for early maturity and development, and is undoubtedly hardy and vigorous. It crosses well with other breeds, particularly Berkshire, Large White, and Large Black.

FEEDING AND MANAGEMENT OF PIGS

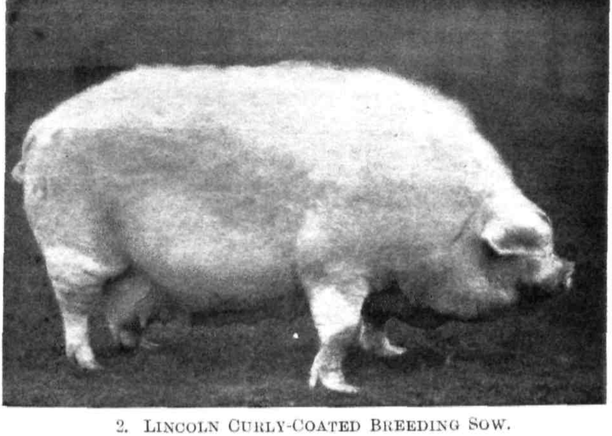
Young pigs usually thrive best when they are born in February, so that it is desirable to arrange for the sow to farrow during this month, as the offspring then have the best months of the year before them. August is the next most favourable month. For the ten weeks after farrowing no food will suit the sow and her pigs better than that of which sharps is the basis, about one-sixth part of broad bran being added.

As soon as the little pigs begin to feed, some skim-milk, placed beyond reach of the sow, should be allowed them, and the quantity may be increased for a time after the piglings are weaned, at six to eight weeks old.

PLATE XV.



1. LARGE BLACK BOAR.



2. LINCOLN CURLY-COATED BREEDING SOW.

From the time of weaning, also, barley-meal should be added to the sharps, and gradually the latter should be withheld, till, at five months old, the food consists almost entirely of meal. If skim-milk is available, it is always useful, as it produces, in conjunction with barley-meal, the choicest of meat. An additional two to three months of such liberal feeding should render the pig fit to kill at a dead weight of some 8 score (160 lb.), being then seven to eight months old, and this should be about 75 per cent. of the live weight. Well-bred pigs, properly fed, will give an increase of 1 lb. of meat for each 5 lb. of meal consumed in the food.

In some cases it is the practice to warm pigs' food before feeding, and no doubt in cold weather the animals thrive better with such treatment. It is very doubtful, however, if the practice is an economical one when a large number of pigs are being fed at the homestead.

Peas, oats, and maize make useful additional foods for pigs, and during their second month, when young pigs are gradually weaning themselves, their appetite should be tempted by frequent small meals of a mixture of such foods.

In the process of fattening pigs, a too exclusive use of maize is liable to render the flesh yellow and flabby; on the other hand, if beans and peas are too extensively employed, the pork is likely to be hard and stringy. The pig is pre-eminently an animal for which a mixed diet is suitable.

The purchased foods, such as sharps, barley-meal, peas, oats, maize, and brewers' grains, constitute the expensive items of pigs' food. Pigs, however, have a special value, in that they will clear up any kind of refuse from the house or dairy. All kinds of food-scraps from the house find their way into the 'wash-tub,' whilst whey and butter-milk from the dairy can always be put to good use in the pig-trough.

It is not always a commendable practice to allow pigs to wander over stubbles after harvest, for by their activity they rapidly reduce any fat they may have acquired, and at the same time their propensity for 'rooting' is greatly encouraged, unless ringing of the

snout has been resorted to. In defence of the practice, however, it may be claimed that the pig is a scavenger, and that, while on the stubbles, the animal is developing frame which can afterwards be filled in when the pig is brought into the yard. The procedure to be followed must be determined according to the object for which pigs are kept.

During summer the food may be varied by the addition of green clover, lucerne, vetches, or even grass, whilst in winter the use of swedes, kohl rabi, mangel, and steamed or boiled potatoes is beneficial. Pigs confined in sties should be allowed a shovelful of mould occasionally, and also some coal and cinders, whilst a lump of rock-salt should always be within access.

A variety of materials may be used for bedding pigs —coarse dried grass, dead leaves, wood shavings, sawdust, moss litter, sea-sand, and all kinds of straw. For sucking pigs, however, wheat-straw should always be employed as litter. Fattening pigs need no litter, and a bare boarded floor will suffice; they usually keep clean the place where they lie.

Because the pig is an omnivorous feeder, the idea has—unfortunately for the pig—become prevalent that he is naturally a dirty animal, and delights to wallow in filth. This is made an excuse for allowing the sty to remain in a condition which is often repulsive. With very little trouble a pig's sty may be kept clean and sweet, besides which it should be roomy and well ventilated, but free from draughts. It should, if possible, have a southern aspect, for pigs love sunshine. On account of their comparatively small stomachs, pigs require their food to be more concentrated than is necessary in the case of cattle or sheep. Frequent feeding, but with no more food than the animals can clean up at each meal, is desirable.

CHAPTER XXVII.

THE FATTENING OF CATTLE, SHEEP, AND PIGS

In Table XXXVI., below, is shown the percentage composition, as determined in the Rothamsted experiments of the carcase of each animal named, the term **carcase** being here employed in the sense in which the butcher uses it, and the term **'store'** being applied to animals not yet put upon fattening food.

TABLE XXXVI.—*Percentage* COMPOSITION *of the* CARCASES *of* CATTLE, SHEEP, *and* PIGS.

	Ash or mineral matter.	Dry nitrogenous substance	Fat.	Total dry matter.	Water.
Fat calf	4·5	16·6	16·6	37·7	62·3
Half-fat ox ...	5·6	17·8	22·6	46·0	54·0
Fat ox	4·6	15·0	34·8	54·4	45·6
Fat lamb	3·6	10·9	36·9	51·4	48·6
Store sheep ...	4·4	14·5	23·8	42·7	57·3
Half-fat old sheep	4·1	14·9	31·3	50·3	49·7
Fat sheep	3·4	11·5	45·4	60·3	39·7
Very fat sheep ...	2·8	9·1	55·1	67·0	33·0
Store pig	2·6	14·0	28·1	44·7	55·3
Fat pig	1·4	10·5	49·5	61·4	38·6

Some instructive facts may be learnt from this table. It shows the large proportion of water which the bodies of animals contain, and it demonstrates that, **as an animal becomes fatter, the percentage of water diminishes.** Further, by comparing (1) the half-fat ox and the fat ox, or (2) the store sheep, the fat sheep, and the very fat sheep, or (3) the store pig and the fat pig, it is seen that, during the accumulation of fat, both the nitrogenous substance and the ash undergo a relative decrease. Notice also that, excepting in the case of the calf, there is a very much larger proportion

of total **fat than of total nitrogenous substance.** In the carcases of fat sheep and pigs, the quantity of fat may be five or six times that of the nitrogenous matter. Observe, further, that the highest proportions of nitrogenous matter and ash are found in the beef-producing animal.

The weights of certain constituents in 1,000 lb. *fasted live weight* of each of the animals already referred to are given in Table XXXVII. The constituents named —nitrogen, phosphoric acid, potash, and lime—are those the removal of which from the soil **necessitates a special**

TABLE XXXVII.—*Quantities of* NITROGEN *and* MINERALS *in 1,000 lb. fasted live weights of* CATTLE, SHEEP, *and* PIGS.

	Nitrogen	Phosphoric acid.	Potash.	Lime.	Total minerals
	lb	lb.	lb.	lb.	lb.
Fat calf	24·49	15·35	2·06	16·46	37·76
Half-fat ox	27·08	18·39	2·05	21·11	46·09
Fat ox	23·18	15·51	1·76	17·92	38·83
Fat lamb ...	19·63	11·26	1·66	12·81	28·88
Store sheep ...	23·69	11·88	1·74	13·21	30·62
Half-fat old sheep	22·59	11·99	1·68	13·50	30·63
Fat sheep	19·71	10·40	1·48	11·84	26·84
Extra fat sheep ..	17·64	11·08	1·58	12·40	28·64
Store pig	21·99	10·66	1·96	10·79	26·50
Fat pig	17·52	6·54	1·38	6·36	16·32

return being made in manure. The phosphoric acid, potash, and lime are, of course, included in the column headed 'Total minerals,' the ingredients of which, in addition to those just named, are iron peroxide, magnesia, soda, sulphuric acid, carbonic acid, chlorine, and silica. Of these, the most important is magnesia, but the highest weight of this is only 0·85 lb. per 1,000 lb. fasted live weight (half-fat ox), whilst it falls as low as 0·32 lb. (fat pig).

The table shows that the nitrogen undergoes a marked decrease in percentage as the animal progresses from

the store to the fat condition. By moving the decimal point one place to the left in the numbers given in the table, it is learnt that, of the beef-yielding animals, the whole body of the half-fat ox contains less than $2\frac{3}{4}$ per cent. of nitrogen, and that of the fat ox less than $2\frac{1}{3}$ per cent. The fat calf is intermediate in this respect, and contains nearly $2\frac{1}{2}$ per cent. of nitrogen. The entire body of the fat lamb yields less than 2 per cent. of nitrogen; whilst, of the mutton-producing animals, the store sheep contains less than $2\frac{1}{2}$ per cent., and the very fat sheep scarcely exceeds $1\frac{3}{4}$ per cent. In the store pig there is $2\frac{1}{5}$ per cent. of nitrogen, but in the fat pig only $1\frac{3}{4}$ per cent.

An inspection of the figures relating to total minerals shows that 1,000 lb. live weight of calves or oxen will carry off much more mineral matter than 1,000 lb. live weight of lambs or sheep, whilst these in their turn carry off more than pigs.

By adding together the 'phosphoric acid' and 'lime figures for each animal, it will be learnt that whilst 1,000 lb. live weight of calves or oxen may carry off from 30 to 40 lb. of phosphate of lime, the same weight of sheep would carry off only about 26 lb. or less, and an equal live weight of pigs much less still. With each description of animal the quantity of phosphate is less in a given live weight of the fatter than of the leaner individuals, and this is particularly the case with pigs.

It is thus learnt that **the production and sale of the animals of the farm** result in carrying off comparatively immaterial quantities of mineral constituents, but that a given weight of oxen carries off more minerals than the same weight of sheep, and the latter more than the same weight of pigs. Four-fifths of the whole, or even more, will be phosphate of lime, whilst the quantity of potash will be very small. On the other hand, the loss to the land, or to the manure from purchased food, will be considerably more in the case of **growing animals** than in that of merely **fattening animals.**

The weight of mineral constituents lost to the farm by mere *fattening* increase is, indeed, almost insignificant

In Table XXXVIII. is recorded the estimated composition of the *increase* during the final four or six **months of the fattening period of oxen, sheep, and pigs:—**

TABLE XXXVIII.—*Calculated* COMPOSITION *of* 100 *Parts* INCREASE *whilst Fattening.*

	Oxen.	Sheep.	Pigs
Mineral matter	1·5	2·0	0·5
Nitrogenous matter	7·7	7·2	7·8
Fat	66·2	70·4	63·1
Total dry matter	75·4	79·6	71·4
Water	24·6	20·4	28·6
	100·0	100·0	100·0

Here, the top line of figures shows that the material which oxen and sheep accumulate during the fattening process does not contain more than from 1½ to 2 per cent. of mineral matter, whilst in the case of pigs it is much less.

Comparing fat animals with other products of the farm, and speaking in general terms, it may be stated that of *phosphoric acid* an acre of land would lose more in milk, and four or five times as much in wheat or barley grain, or in hay, as in the fattening increase of oxen or sheep. Of *lime* the land would lose about twice as much in the animal increase as in milk, or as in wheat and barley grain, but perhaps not more than one-tenth as much as in hay. Of *potash* an acre would yield only a fraction of a pound in animal increase, six or eight times as much in milk, perhaps twenty or thirty times as much in wheat or barley grain, and more than one hundred times as much in hay.

The loss of minerals to the land in animal increase has been seen to consist chiefly of phosphate of lime, and the quantity ranges from 5 to 10 lb. per acre. In *milk* the loss is greater in phosphoric acid, less in lime,

and more in potash. In *wheat and barley grain* the loss of phosphoric acid is several times as great, and it is chiefly as phosphate of potash; whilst in *hay* the loss of phosphoric acid is much the same as in wheat and barley grain, but that of both lime and potash (especially of the former) is very much greater than in any of the other products.

Another view of the exportation of mineral matter from the farm through the agency of animals may be obtained by the consideration of individual cases. Thus, a *calf* weighing 160 lb. carries off less than 10 lb. of minerals, including between 8 and 9 lb. of phosphate of lime and about ½ lb. of potash. An *ox* weighing from 1,200 to 1,400 lb. carries off from 55 to 60 lb. of minerals, including less than 50 lb. of phosphate of lime, and about 2½ lb. of potash. A *fat lamb* carries off about 2½ lb. of minerals, including about 2 lb. of phosphate of lime, and from 2¼ to 3 oz. of potash. A *store sheep* carries off less than 3 lb. of minerals, including over 2½ lb. of phosphate of lime, and from 2¼ to 3 oz. of potash. A *fat sheep* takes away from 3¼ to 3½ lb. of minerals, including 2½ to 3 lb. of phosphate of lime, and from 2¼ to 3 oz. of potash. A *very fat sheep*, of 240 lb. live weight, carries away more than 7 lb. of minerals.

It must not be supposed that a 'lean' animal contains no fat. On the contrary, it has been proved by analysis (*see* Table XXXVI.) that such animals as a half-fat bullock, a lean young sheep, and a store pig, may contain, in their entire bodies, more *dry fat* than *dry nitrogenous* substances. Of animals 'ripe' for the butcher, a bullock was found to contain rather more than twice as much dry fat as nitrogenous substance; a moderately fat sheep nearly three times as much; and a very fat one more than four times as much. A moderately fat pig contained in its entire body about four times as much dry fat as dry nitrogenous matter. A fat calf yielded rather less fat than nitrogenous matter, a circumstance quite in accordance with the recognized character of veal, the leanness of which is the reason that fat bacon is eaten with it: the pig supplying fat in which the calf is deficient.

CHAPTER XXVIII.

DAIRYING

The increased demand for milk, butter, and cheese—especially for the first-named product—has led to the rapid development of the important branch of the agricultural industry known as Dairy Farming. Many holdings are worked exclusively as dairy farms; others, again, are mixed farms upon which dairying is only one of two or three leading features, such as sheep-breeding and corn-growing. Independently, however, of such farms as these, it is a common custom, on other kinds of farms, to keep a few cows for the sake of the milk and butter which they yield.

MILK

Milk, like gastric juice, bile, pancreatic juice, saliva, and urine, is a secretion. It is prepared from the blood by the activity of the cells that make up the mammary glands (fig. 212), which are contained in the cow's udder, or milk-bag. This latter is provided with four delivery tubes, or teats, each of which, with its gland, is termed a 'quarter.' When a cow is said to have 'lost a quarter,' it means that one of the teats has ceased to yield milk. Besides the external covering which binds together the whole of the udder, each gland has its own special fibrous envelope, and is distinct from, and independent of, the other glands; hence, though the function of one gland, or 'quarter,' may be impaired, the others may continue to act in the usual way. The orifice at the free end of the teat is a narrow tube, which is ordinarily closed. In the body of the teat this tube is much wider, but becomes constricted again at the region where the teat merges into the udder. Above the constriction is a large space (the 'milk cistern,' or reservoir), which becomes distended with milk as the secretion accumulates. Into each of the four milk cisterns innumerable tubes open. Any one of these may be traced back into

minute tubes or ducts, which end blindly in several small sacs or bags called alveoli (Lat. *alveolus*, a little hollow). The delicate walls of the ducts and the alveoli are lined by a single layer of minute living cells, and it is these which are the secretory part of the mammary gland. The whole gland is richly supplied with blood by means of thin-walled blood capillaries, a dense net-

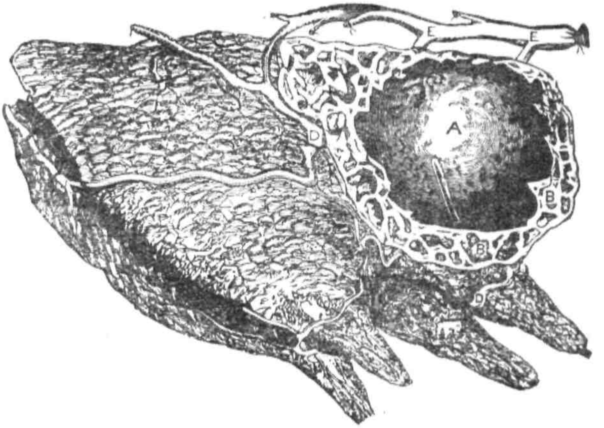


FIG. 212.—COW'S UDDER STRIPPED OF ITS SKIN.

One of the anterior glands cut open in order to expose—
A, the milk cistern or reservoir, into which a tube is seen to be passed through the teat, and around which are smaller reservoirs, B.
D, mammary veins.
E E, origin of the superficial abdominal vein, or 'milk vein.'
On the left side of the figure is seen the outer surface of the posterior glands, which have a lobulated appearance, produced by bundles of milk ducts collected together.

work of which surrounds every alveolus. Out of the blood thus placed at their disposal the secreting cells manufacture milk, which flows along the ducts, and accumulates in the milk cistern at the top of each teat. The general plan, here described, upon which the mammary glands are constructed, is similar to that of the salivary glands of the mouth.

The details of the method whereby the secreting cells of the mammary gland prepare milk from the blood which is submitted to their action are too intricate to be discussed here. But, inasmuch as milk is prepared from the blood, it is useful to notice the **resemblances and differences between blood and milk.**

Blood consists of a liquid plasma, or medium, in which are suspended enormous numbers of microscopic solid bodies called *corpuscles*, and the red colour of the great majority of these imparts the characteristic tint to blood (*see* p. 435). Physically, milk resembles blood, in that it also consists of a watery fluid in which are suspended immense numbers of minute solid bodies, the *fat globule*, which impart to whole milk its very faint yellow appearance.[1] The opacity of separated milk, from which most of the fat globules have been removed, is possibly due to the condition of some of the casein, for this ingredient is not all in a state of true solution. Blood is slightly heavier than milk, the specific gravity of the former being 1·055, and of the latter 1·032. Blood placed in contact with non-living matter, as in a basin, speedily coagulates (*see* p. 435); milk in similar circumstances does not. Coagulated blood consists of a soft clot (corpuscles bound together by fibrin) and liquid serum. In round numbers the percentage composition of the serum is—of water, 90; of nitrogenous substances, from 8 to 9; of fat, extractives, and saline matters, from 2 to 1.

Of the blood corpuscles there are two kinds, the red and the colourless (*see* p. 435). The former are nearly a thousand times as numerous as the latter, and contain 56·5 per cent. of water, and 43·5 per cent. of solids, the latter being almost entirely nitrogenous organic matter. The fibrin is also made up of nitrogenous organic matter. When the corpuscles, on the one hand, and the serum, on the other, are dried and ignited, and their ashes analyzed, the leading mineral constituents of the cor-

[1] The fat globules vary in size from $\frac{1}{2500}$ to $\frac{1}{25000}$ of an inch in diameter. They are largest in the milk of the Channel Islands breeds.

puscles are found to be the chloride and phosphate of potassium, and of the plasma soda and chloride of sodium. The extractives of the blood, though not abundant in quantity, are numerous and variable, the chief ones being urea, kreatin, sugar, and lactic acid. These details serve to show what a very complex fluid the blood is, and what is the nature of the materials from which the mammary gland has to elaborate the milk.

The Blood Supply of the Mammary Gland.—The course taken by the blood on its way to and from the mammary gland should be understood. The arterial blood is pumped from the left side of the heart into the aorta, passing along which the blood reaches the external iliac artery (p. 437), and this is continued on into the femoral artery, extending more or less parallel to the femur, or thigh-bone. The femoral gives off a branch, the prepubic, which in turn gives off a branch, the external pudic, and this, after passing through the inguinal ring, divides into two branches, the anterior, or subcutaneous abdominal artery, and the posterior abdominal, or mammary artery. It is from these that the blood supply of the capillaries of the mammary gland is immediately derived; of the two, the *mammary artery* is the larger.

The blood, after passing through the capillaries of the mammary gland, is collected into the abdominal subcutaneous vein, commonly known as the 'milk vein.' In cows, this vessel is particularly large; it extends along the under surface of the abdomen to near the end of the sternum, or breast-bone, where it turns inwards to join the internal thoracic, or internal mammary vein, the openings in the abdominal wall through which these vessels pass being known as the 'milk fountains' or doors. The internal mammary conveys its blood to the vein of the fore-limb, and this joins the anterior vena cava, which empties into the right auricle. By this route, then, the blood which has been submitted to the action of the mammary gland is returned to the heart.

The average percentage composition of cow's milk

is shown in the first column of figures in Table XXXIX., and, for the purpose of subsequent reference, that of skim-milk and that of whey are placed alongside.

The albuminoids, or nitrogenous compounds, are casein and albumin, the latter in ordinary cow's milk constituting not more than one-ninth of the total albuminoids. The ash consists of lime, potash, soda, magnesia, and iron, with phosphoric acid and chlorine. The figures relating to skim milk show that most of the fat is removed in the cream. It is further apparent that the liquid part of the milk, after separation of the fat globules, still retains all the milk-sugar and most of the albuminoids. It is worthy of note, too, that skim milk contains the same proportion of water (90 per cent.) as the serum of blood.

TABLE XXXIX.—*Percentage* COMPOSITION *of* WHOLE MILK, SKIM MILK, *and* WHEY.

	Whole milk.	Skim-milk.	Whey.
Water	87·10	90·0	93·4
Albuminoids (casein, albumin) ..	3·50	3·7	0·9
Milk-sugar (lactose)	4·75	4·8	4·8
Fat (butter)	3·90	0·8	0·3
Ash	0·75	0·7	0·6
	100·0	100·0	100·0

Hence the mammary gland, by the activity of its secreting cells, appears to be capable of preparing, from the blood, typical representatives of **the three great classes of food-stuffs**—(1) proteins, albuminoids, or nitrogenous organic compounds, represented by the casein and albumin; (2) carbohydrates, represented by the milk-sugar; (3) fats, represented in the fat or oil globules.

It is because it contains these three classes of bodies in suitable proportions, together with an appropriate addition of mineral matter, that milk furnishes what is called a **'perfect food'** for the young animal. The

student will again specially note that milk is obtained from the blood, and he has already learnt (Chapter XIX.) that blood is dependent for its nourishment upon the food. In accordance with this it is possible, within certain limits, to so modify the food of the cow as to regulate the quantity and quality of the milk which she yields.

The composition of cow's milk varies—(*a*) in different breeds, (*b*) in different animals of the same breed, (*c*) in the same cow at different periods, and even (*d*) in the earlier and later portions of the same milking. This last variation is due to some separation of the fat globules, or cream, taking place whilst the milk is still in the udder, in consequence of which the milk is richer in fat the later it is drawn in the same milking, whilst the milk last drawn of all—the 'strippings'—is often very rich in fat.

The amount of solid matter contained in different samples of milk may fall as low as 10 per cent. and rise as high as 16 per cent., corresponding respectively to 90 per cent. and 84 per cent. of water. But it is noteworthy that such poor milk as contains as much as 90 per cent. of water yet includes more solid matter than turnips, which (p. 457) possess on an average about 92 per cent. of water.

The milk yielded by the cow directly after calving is called *colostrum*, and it differs from the ordinary milk in its high proportion—20 per cent. or more—of albuminoids, whilst the water does not much exceed 70 per cent., and the sugar about 3 per cent. Colostrum is specially suited to the needs of the new-born calf, and is exclusively used for that purpose. A cow is usually in full milk—that is, the flow is more copious—from the second to the seventh week after calving. The yield then begins to diminish in quantity, till eventually the cow 'goes dry.' By a plentiful supply of well-selected food, however, it is possible to materially prolong the period of most copious flow.

It is evident, from the amount of albuminoids in milk, that **dairy cows require a nitrogenous diet**, and that they should not be fed on the same kind of food

as will serve in the case of a fatting bullock. Young grass and growing clover afford the kind of food which is necessary. On the other hand, where, from circumstances of situation or season, hay, straw, and chopped roots have to be largely employed, these must be supplemented by such nitrogenous foods as cake, or peas, or beans. Bruised oats and wheat-bran are good foods for cows in milk, whilst green fodder of all kinds and brewers' grains, will increase the yield. It is thus possible to improve the quality of cows' milk by adding to the diet cake, beans, etc., and to increase the quantity by the use of succulent foods.

If a cow has to rely chiefly upon a large quantity of poor herbage, or other watery food, the milk will correspondingly become poorer in solids, the butter-fat being the constituent most likely to fall in quantity. When cows are kept for the sake of butter, such additional foods as oats, wheat-bran, malt-dust, and cotton-cake give excellent results, whilst palm-nut meal is also useful. Peas, on the other hand, are likely to produce a hard butter, and linseed-cake, if given too freely, a soft oily butter. Where roots are fed to milch cows, the mangel is far preferable to swedes and white turnips, on account of the undesirable flavour the latter are liable to impart. Cabbages are superior to either of these. Kohl-rabi, carrots, and parsnips are also useful succulent foods, but in all cases decayed leaves should be removed. Brewers' grains (wet) should not be given to cows at the time of calving.

Estimate of Cost for Keeping a Dairy Cow for One Year.

Winter.—26 weeks.

	Cost per head, per week. £ s. d.	£ s. d.
Daily ration —		
*Roots, 32 lb. ...	0 0 8	
Cake, 3 lb. / Meal, 3 lb. ...	0 2 10	
†Hay, 16 lb. ...	0 2 0	
		0 5 6
	Labour ...	0 1 6
	Total cost per week ...	0 7 0

Summer.—26 weeks.

	£	s.	d.	£	s.	d.
Pasture, say	0	2	0			
Undec. cotton cake, 3 lb. per day ...	0	1	0			
				0	3	0
Labour ...				0	0	6
Total cost per week ...				0	3	6

	£	s.	d.	£	s.	d.
26 weeks at 7*s*. per week	9	2	0			
26 weeks at 3*s*. 6*d*. per week	4	11	0			
For depreciation and risk for year ...	2	2	0			
				15	15	0

Returns from an average Dairy Cow.

Milk Selling.

	£	s.	d.
600 gallons of milk at 7*d*. per gallon	17	10	0
Calf	1	10	0
	£19	0	0

The **production and sale of milk** are much more exhaustive of the food resources of a farm than are the fattening and sale of cattle (p. 546), and the manure from dairy cows is much less valuable than that from stall-fed oxen (p. 464). Where cheese is made, and the whey is fed on the farm, the loss is less; and it is less still where butter only is sold, and the skim milk is used on the farm. Butter is essentially a carbonaceous product, and the farmer gets carbon from the air for nothing. The student who has read thus far ought to be able to give the reasons for the facts stated in this paragraph.

Milk Records.—Although the practice of keeping careful records increases year by year, the number of recorded herds is still extremely small. The quantity

* Roots valued at 8s. per ton as the consuming value.

† Hay valued at £2 per ton as consuming value.

and quality of milk yielded by different cows varies considerably, so in order to get the best returns it is imperative to weed out unprofitable animals, keeping and breeding from the best. Hence the necessity of exact milk records, for these alone can give the necessary information. A difference of one pint at each milking would, during an average milking period of 300 days, amount to no less than 75 gallons, which, if sold at, say, 8*d.* per gallon, would realize 50*s.* A well-kept record not only makes it possible to determine the value of individual cows, but also shows the influence of a change of pasture or food, the effect of different climatic conditions, and so forth. In fact, the useful knowledge obtained far more than counterbalances the trouble and expense incurred in keeping the record.

A **milk recorder**, or balance (fig. 213), is used for determining the weight of milk produced. This should be entered on a weekly Milk Return, drawn up in the following form:—

WEEK ENDING SATURDAY 19

Name of Cow.	SUN.		MON.		TU.		WED.		TH.		FRI.		SAT.		Total.
	M.	E.	M.	E.	M.	E.	M.	E.	M.	E.	M.	E.	M.	E.	
Total ...															
To calves ..															
To dairy ..															

M = morning's milk. E = evening's milk.

At the end of each month the weekly results are collected into a Monthly Milk Register, and these again are embodied in an Annual Milk Register at the end

of the year, the following headings being used in both cases:—

Name of Cow.	Breed.	Age.	Date of Calving.	No. of Days in Milk.	Milk in lbs.	Daily Average.	Percentage of Cream.	Percentage of Butter-fat.	Remarks.

The *weight* of the milk is taken in preference to the *volume*, because it can be determined with greater accuracy. A gallon of milk of average quality weighs about 10·32 lb. An approximate milk record can be obtained by weighing each cow's milk on one day—preferably the middle day of each week—and entering the weight given as the daily average for the week. At the end of the year these assumed weekly averages are added together and multiplied by seven, the total thus obtained approximating closely to the actual weight yielded for the year.

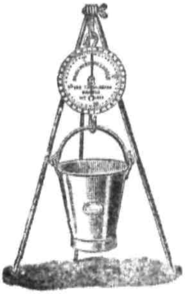


Fig. 213.—Milk Recorder.

Determination of the Percentage of Cream.—For this purpose the instrument generally used is the **creamometer,** which is simply a glass tube marked with a graduated scale, divided into one hundred equal parts. The tube is filled with milk, and when the cream has risen its percentage volume can easily be read on the scale. The test is only a rough one, for cream is not a substance of constant composition, and its amount varies with different circumstances—*e.g.*, if milk has been much shaken, as by a long railway journey, the volume of cream obtained is reduced. In spite of these objections the creamometer is very useful when the milk of cows in the same herd is to be compared, though to give a reliable result the different samples must be treated in precisely the same way.

Determination of the Percentage of Butter-fat.—The best and quickest results in testing for butter-fat are obtained by the Gerber Milk Tester (fig. 214), a centrifugal machine, in which specially shaped test-bottles are revolved for about five minutes at a fair speed. The narrow graduated parts of the test-bottles are directed to the centre of the machine, so that the lighter fat remains in them after centrifuging, and its amount can be read off on the graduated scale. Before treatment each test-bottle is filled with 11 c.c. of milk, 10 c.c. of dilute sulphuric acid, and 1 c.c. of amyl alcohol,

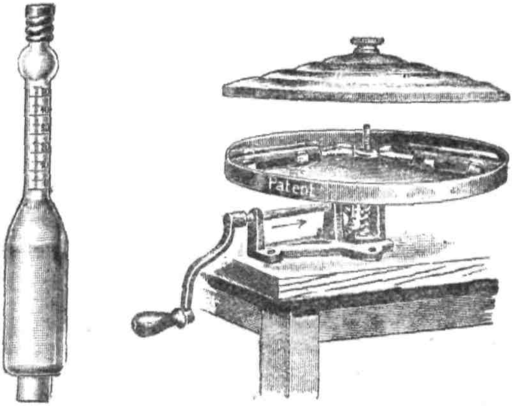


FIG. 214.—GERBER MILK TESTER.
One tube is shown separately to left.

the object of these additions being to dissolve the casein, etc., thus liberating the fat in an oily form, this being further aided by keeping the machine at a fairly high temperature. Exact details are supplied with each machine.

The importance of accurate milk records to the dairy farmer and breeder can hardly be over-estimated. They not only enable 'wasters' to be weeded out, but also supply the information necessary for establishing profitable milking herds. It must not be forgotten in this connection that only bulls from a good milking strain

should be used in breeding dairy cattle, for the hereditary characters derived from the male parent are fully as important as those derived from the female, perhaps even more so. Careful attention must also, of course, be given to the general character and points of the animals selected for building up and improving a herd. Jersey cattle afford an excellent illustration of the establishment of a butter breed by breeding continuously on the lines indicated.

MILKING.—There is no farm operation which requires more skill, when effectively carried out, than that of milking. We must bear in mind that dairy cows are sensitive creatures; therefore to ensure the best results they should be treated quietly and kindly. There should be no talking or noise permitted in the sheds, and the operation should be quickly and thoroughly carried out, for the more expeditious and complete the milking the better the result. A special method, known as the 'Hegelund system' (named after Professor Hegelund, who introduced it), is much practised in Denmark; but it requires too much time to suit most English farmers. It consists of a method of manipulation of the udder, in the belief that more milk is obtained.

The milker should always speak to the cow when approaching, taking the stool in the left hand and the milk-pail in the right, and bringing the stool into position as he sits down. Commence the front quarters first, by taking the nearer teat in the left hand and reaching across to the other with the right hand. The fingers should pass partly round the teats, and then the points of the fingers turned in, so as to press the teats against the palm of the hand. There should be no pulling or jerking. The motion should come from the wrists, and not from the elbow. There is a bad practice amongst some milkers of drawing the thumb and first finger down the teat, and this should be condemned, for it has a tendency to produce sore teats and results in a shrinkage in the milk supply. To keep the udder shapely and encourage milk in the fore-quarters, these should not only be milked first, but *stripped again* after the hind-quarters have been dealt with.

Cleanliness.—As milk is commonly recommended for infants and invalids, and is peculiarly liable to contamination, the greatest care should be taken to secure cleanliness. The sheds should be kept as clean as it is possible to keep them, when necessary the cows should be well groomed, especially the hind quarters, to remove any dirt, and the udder washed or wiped well with a damp cloth before milking commences. If stalls are properly constructed, grooming will be reduced to a minimum, and the washing of udders saved almost completely. Such washing should be avoided as much as possible, or udder trouble may result.

'The mistake in cowsheds is that too often the mangers are placed at the same height as if for a horse, and the standings are made too wide and too long. Mangers for cows should be on the floor level. The length from the wall or back of the manger to the back of the stall, or standing, should be just sufficient for the cow to stand up or lie down in, her head in both positions being over the manger. The width of the stall should be enough to let her stand and lie down straight, without being able to turn round and lie across it. The gutters behind the stalls should be eight inches deep and of sufficient width to allow shovels and brooms to be used freely for cleaning out the manure.

'The cows should be fastened by the neck with a chain or strap attached to a ring on a short length of chain, with a swivel, working up and down a bar of iron two feet long, which should be fastened vertically to the side of the stall about two inches in front of the manger. The chain or strap should be tied to the ring with cord, so that in the event of anything going wrong with the cow, the cord can be cut at once and the animal set free.

'I give below the measurements of cow stalls, each to hold two cows. I have found by experience that in stalls of these dimensions the cattle will be comparatively clean. Two sets of figures have been given to suit the larger and smaller breeds of cattle:—

	Shorthorn.		Jersey.	
	ft.	in.	ft.	in.
Total length of stall from outside wall of manger to back of the standing .	7	3	6	9
Width of stall to take two cows . .	8	0	7	0
Width of manger from front to back .	1	10	1	10
Depth of manger from front to back .	0	9	0	9
Depth of gutter behind cows . .	0	8	0	8
Width of gutter	2	0	2	0
Height of hay rack from bottom of manger to bottom of hay rack .	4	0	4	0
Height of hay rack	2	0	2	0

'The floor of the stalls should be level, and both the stalls and the gutter should be well littered with straw.

'In such standings cattle should keep clean, while with more room they will be found to get dirty. . . . The great secret in building cow stalls is to make the cows lie down exactly in the same spot where they stand to feed, and this can only be attained by building the mangers on the floor level and of such a height that the cows can rest their heads over the manger when lying down.' (Ernest Mathews, Journal R.A.S.E., vol. 67, 1906, pp. 119-20.)

Milking through gauze, as is done in Jersey, can be recommended.

The milkers should wash their hands well before commencing to milk, and also rinse them after completing each cow, as this will obviate teat trouble. A clean overall or apron should be worn, which must be kept for milking only, and replaced with a clean one as soon as it becomes soiled. The intervals between the times of milking should be as nearly equal as possible, for the longer the interval between the times of milking the poorer will be the milk, and *vice versâ*. A strict lookout must be kept for any udder troubles, great care being taken not to use milk from a cow suffering from garget, or cold in the udder, as the milk from one cow so affected will spoil the whole lot if mixed with it.

Fig. 215.—Milk Strainer.

Treatment of Milk.—As soon as the milk has been drawn from the cow it should be taken away from the sheds or byre, for milk quickly absorbs odours, and is thus liable to become tainted if left in the sheds for any length of time. The milk should then be strained. The best kinds of strainers (fig. 215) are those containing a pad or medium of prepared cotton wool, which removes the very finest particles of dust or dirt that would pass through the ordinary gauze strainer.

Cooling.—Where the milk is sold in bulk, and has to be sent any distance by rail, it is necessary to reduce its temperature, to prevent it from becoming sour. This is done by passing the milk over a **refrigerator** (fig. 216), through which a constant stream of cold water is running. If the milk can be reduced to a temperature of 50° F., it will travel a long distance without becoming sour, providing the vessel in which it is placed be clean and sweet.[1] The most convenient method of conveying the milk is in large cans, commonly called 'milk churns.' These so-called milk churns are made of tinned steel, and hold 17 imperial gallons or 8 barn gallons (1 barn gallon equals 17 pints).

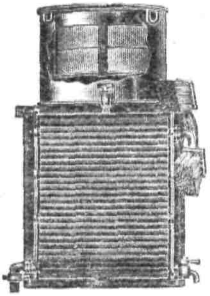


FIG. 216.—REFRIGERATOR.

When the milk is kept at home for **cheese-making**, it should be removed to the dairy as soon as it is drawn, and passed through a sieve into the **vat** or **milk-tub**, where it should be allowed to stand over-night. The next morning the cream is skimmed off, added to the morning's milk and returned to the vat (*see* p. 573). If the weather is very hot and thundery, or if there is a considerable quantity of milk, it is a good plan to run a little cold water into the jacket which surrounds the milk, stirring occasionally to reduce the temperature and prevent the milk from becoming over ripe.

Milk intended for **butter-making** may be passed through a separator or set in pans. In either case this must be done whilst the milk is fresh and warm from the cow to get the best results. If it is to be **set in pans**, they should be covered with muslin, and placed in a cool, light, airy room, free from objectionable smells or odours. The pans should never be placed in a living room or larder where meat or any strong smelling foods

[1] It is important always to use a *correct* thermometer when temperatures have to be determined.

are kept. To get the best results from setting, the room should be about 50° lower than the temperature of the milk, and the pans should be left undisturbed for 24 to 36 hours before skimming. The time will vary according to the season of the year and the keeping properties of the milk, but in any case the cream must be skimmed off before the milk turns sour, or a very unpleasant flavoured butter will be produced. (For the after treatment or ripening of the cream, *see* p. 567.)

SEPARATORS (fig. 217).—These important appliances, of which the first continuous working form was invented by De Laval, are put on the market by many manufacturers, and are made of various sizes, capable of dealing with from 9 to 880 gallons of milk per hour. The principle is the same in all, the milk and cream being 'separated' by means of centrifugal force. The milk is allowed to run into a bowl, which generally contains a number of discs arranged so that the liquid is centrifuged in thin layers, which largely increases the separating capacity of the machine and greatly reduces the necessary speed. A great saving of labour is thus effected, and wear and tear of the running parts of the machine reduced to a minimum. During separation the butter-fat, which is the lighter part of the milk, passes to the centre, together with a little casein, water, etc., which with it form the **cream**, and this goes through a small opening called the **cream-screw**, and is delivered through an outlet tube into a vessel placed to receive it. The **separated milk** passes to the outside of the discs, and flows out through a separate tube. When all the milk has passed through the separator it is a good practice to run a little separated milk or warm water through, as this will remove the cream that remains in the bowl, and which would otherwise be lost.

The **conditions necessary for successful separation** are as follows:—

1. The machine must be in proper working order and set on a firm foundation so as to be perfectly free from vibration when running.
2. It must be well lubricated with a suitable oil.
3. The speed of the bowl must be up to and kept at the stated rate before turning on the flow of milk.

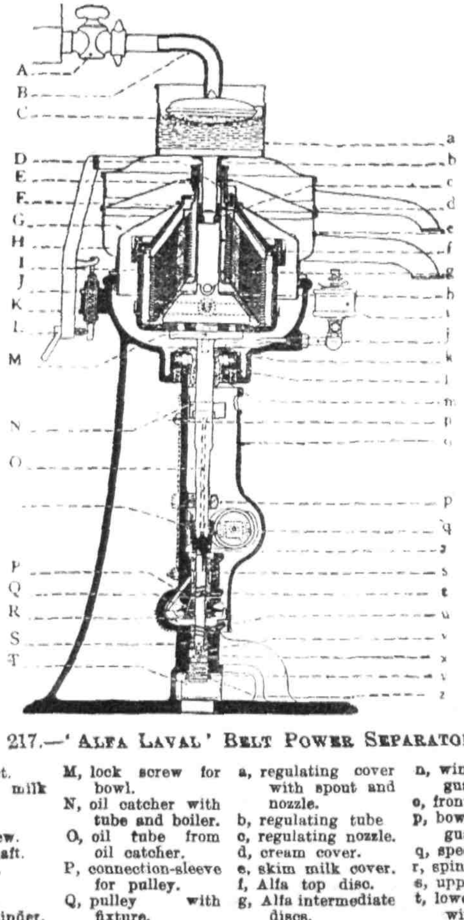


FIG. 217.—'ALFA LAVAL' BELT POWER SEPARATOR.

A, milk faucet.
B, outlet for milk faucet.
C, float.
D, cream screw.
E, tubular shaft.
F, bowl hood.
G, hood ring.
H, bowl ring.
I, bowl cylinder, with spindle.
J, fixture for cover arm.
K, cover arm with hook.
L, wing screw for cover arm.
M, lock screw for bowl.
N, oil catcher with tube and boiler.
O, oil tube from oil catcher.
P, connection-sleeve for pulley.
Q, pulley with fixture.
R, union nut for pulley.
S, waste-oil tube.
T, waste-oil cup.
a, regulating cover with spout and nozzle.
b, regulating tube.
c, regulating nozzle.
d, cream cover.
e, skim milk cover.
f, Alfa top disc.
g, Alfa intermediate discs.
h, Alfa bottom disc.
i, sight-feed lubricator.
j, lubricator fixture.
k, spring housing.
l, top-bearing plate.
m, top - bearing brass.
n, wing screw guard.
o, front guard.
p, bowl spind guard.
q, speed indicat
r, spindle-cup.
s, upper bushing
t, lower spind with steel poi
u, lower bushing.
v, steel point.
x, tread - whe pair.
y, bottom screw.
z, lock nut f bottom screw.

4. The milk must be at a suitable temperature, *i.e.*, 95° F. to 100° F.

5. The milk must be well strained before separating to remove hairs, etc., which are the cause of much trouble if left in the milk.

Starters.—Before milk is employed for making butter or cheese it is allowed to stand for a time in order to 'ripen,' or develop a certain amount of acidity, a process brought about by the action of lactic acid bacteria. These are introduced by means of what is technically known as a **starter.** The starters used at the present day may be divided into two classes:—

(1) The home-made or natural starters.
(2) The commercial or culture starters.

The starters in the first class generally consist of sour milk, butter-milk, or whey, and in each case the process of ripening has taken place under ordinary conditions in the dairy, and so we may have present in the starter any number of different kinds of bacteria. If, however, the cows are properly fed and tended, and the dairy work good, and carried out with scrupulous regard to cleanliness, the risk of undesirable bacteria is minimized, and some authorities are of opinion that natural starters are preferable under such conditions.

The starters in the second class—viz., the **culture starters**—are prepared by bacteriologists, and may contain one or more kinds of bacteria, which have been specially selected on account of their ability to produce desirable ripening. Hansen's lactic ferment powder is a culture widely used in this country. This culture is said to consist of two sorts of lactic-acid producing organism.

This form of starter requires 'building up' before use, and this is done by adding the ferment powder to a gallon of fresh separated milk which has been previously heated up to 180° F., and cooled to about 70° F. It is then left in a cool, well-ventilated room at about 60° F., covered over with a piece of butter muslin, or, better still, a disc of cotton-wool, and left

for 24 hours. At the end of this time the top layer is skimmed off and discarded, and the remaining portion is stirred well, a half-pint is taken and added to a gallon of fresh separated milk, treated as before, and again allowed to stand for 24 hours. This is repeated for 2 or 3 days, when the milk will be softly coagulated, and will be ready for use. **Milk starters** can be obtained from the leading dairy schools and dairy firms. They have been built up from commercial starters, and are more convenient to dairymen and farmers—

(1) Because they are ready for immediate use.

(2) Because the cost is very small. Half a pint of such a starter can be purchased for 1*s*., and this is sufficient to propagate one gallon of milk.

In propagating a starter the greatest care must be taken to prevent it from becoming too ripe, as this tends to weaken the desirable bacteria, with the result that the starter undergoes fermentation by undesirable germs, which produce objectionable flavours in cheese and butter.

The quantities of such a starter to use for **cheese-making** will vary from 1 to 2 per cent., according to the season of the year. Care must be taken to pass the starter through a sieve, and to stir the milk well for a few minutes, so as to effect thorough and even mixture. The milk is then allowed to stand for about 15 minutes before adding the rennet.

For **butter-making** from a quarter to half a pint of starter is added per gallon of cream to the first batch of cream placed in the ripening vat or tin. This should be well stirred in and added to the cream after it has been cooled to between 60° and 70° F., the sooner after separating the better. As each lot of fresh cream is added to the bulk it must be thoroughly stirred, care being taken to see that the cream has cooled below 70° F. before adding to the bulk. Cream so treated will be ready for churning in from 3 to 4 days; in any case it is always better to churn twice a week than to allow cream to collect for a whole week before doing so.

BUTTER

The first object of the butter-maker should be to get the cream properly and thoroughly **ripened,** for no matter how skilful a person may be, he or she cannot produce good butter from a badly-ripened or poor-flavoured cream.

Pasteurization.—For the purpose of producing good even-flavoured cream **pasteurizing** is often recommended. This simply consists in raising the temperature of the cream as soon as it is skimmed or separated to about 150° F., and then cooling to 60° F. A quantity of starter should then be added, as mentioned previously, and the cream stirred well twice each day to get proper aeration and uniform ripening. The cream should be added from the subsequent meals, after pasteurizing and cooling, and well stirred.

The heat to which milk is exposed during pasteurization kills many of the bacteria which are present, especially those which are the agents of certain infectious diseases, and the addition of artificial cultures to pasteurized milk introduces bacteria of which the action is known. The dairy authorities who object to the use of commercial starters also object to pasteurization, which they consider unnecessary when milk is properly handled from the first, likely to conduce to carelessness, and detrimental to the quality of the butter.

Never mix fresh cream to that which is already ripened the same morning of churning, for such a practice results in a loss, as ripe cream churns more quickly than sweet cream, and so the sweet cream or the greater bulk of it would pass off with the buttermilk and be lost to the dairy. At least twelve hours must elapse from the addition of the last lot of cream to the time of churning.

Cream may be regarded as a highly concentrated milk, exceedingly rich in fat. The object in butter-making is to isolate this fat—that is, to separate it from everything else that is associated with it in milk. Each

little mass of fat, as it occurs in milk, exists as a minute independent globule. In order to get the globules of fat to run together, **churning** is resorted to. Many kinds of churns (fig. 218) are in use, but in all of them the object is the same, no matter how it may be effected. A good churn should be simple in construction, and therefore easy to clean. The residual liquid, after the butter has separated from the cream that is put into the churn, is called *butter-milk*.

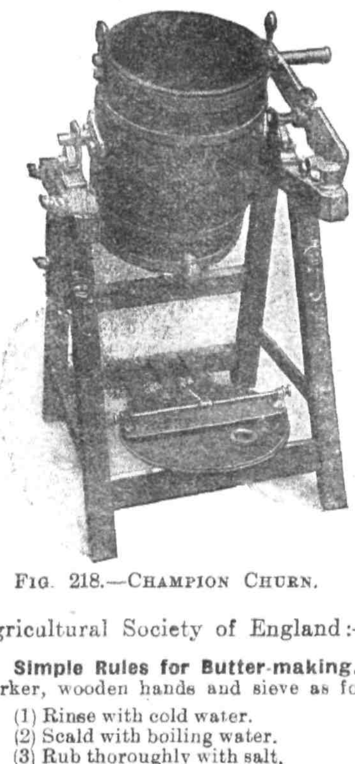


FIG. 218.—CHAMPION CHURN.

The following instructions have been published as a leaflet by the Royal Agricultural Society of England:—

Simple Rules for Butter-making.—Prepare churn, butter worker, wooden hands and sieve as follows:—

(1) Rinse with cold water.
(2) Scald with boiling water.
(3) Rub thoroughly with salt.
(4) Rinse with cold water.
Always use a correct thermometer.

The cream, when put into the churn, and the churn should both be at a *temperature* of 52° to 57° in summer, and 56° to 60° in winter. The temperature of the atmosphere should decide at which of these figures churning should take place. The warmer the day the lower should be the temperature of the cream and the churn, and *vice versa*. The churn should never be more than half full. Churn at number of revolutions suggested by maker of churn. If none are given *churn at 40 to 45* revolutions per minute. Always churn slowly at first.

Ventilate the churn *freely* and frequently during churning, until no air rushes out when the vent is opened.

If the cream 'goes to sleep' after it has been churned for *25 to 30 minutes, stop churning and wash down the lid and sides* of the churn with a small quantity of water at a temperature of from 75° to 80° Fahr. The butter will usually come with a few more revolutions of the churn.

Stop churning immediately the butter comes. This can be ascertained by the sound, or by inspection.

Directly the butter comes, the temperature of the butter and butter-milk in the churn should be taken, in order that the cold water and brine mentioned in the three following paragraphs may be lower in temperature than the butter and butter-milk, otherwise in the washing and brineing processes the butter will not be kept in good grain, but may get into a lump. Butter, when churning is properly done, should be like grains of mustard seed.

Pour in a small quantity of cold water (one pint water to two quarts cream) to harden the grains, and give a few more turns to the churn gently.

Draw off the butter-milk, giving plenty of time for draining. Use a straining cloth placed over a hair sieve, so as to prevent any loss, and wash the butter in the churn with plenty of cold water; then draw off the water and repeat the process 3 or 4 times, until the water comes off quite clear.

To brine butter, make a strong brine, 1 to 3 lb. of salt to 1 gallon of water. Place straining cloth over mouth of churn, pour in brine, put lid on churn, turn sharply three or four times, and then drain off the brine.

When a Délaiteuse or centrifugal drying machine is used, the butter should be taken out of the churn and put in the bag provided for the purpose, and dried in the machine.

Where the water is worked out of the butter on the butter worker only, the butter should be lifted out of the churn into a sieve, turned out on the worker, and allowed to drain for half-an-hour (that is, if the dairy is cool) before being worked.

In both cases, working out the superfluous moisture and not working water into the butter is the object to be attained.

To drysalt butter, place butter on worker, let it drain 10 to 15 minutes, then work gently till all the butter comes together. Place it on the scales and weigh; then weigh salt, for slight salting ¼ oz., medium ½ oz., heavy salting ¾ oz. to the lb. of butter. Roll butter out on worker and carefully sprinkle salt over the surface, a little at a time; roll up and repeat till all the salt is used.

N.B.—Never touch the butter with your hands.

The **centrifugal drying machine**, or Délaiteuse, mentioned above, essentially consists of a perforated metal cylinder, worked by a horizontal spindle and surrounded

by an outer case. About 16 lb. of the granular butter is put in a canvas bag and placed in the cylinder, which is revolved for about four minutes at the rate of 700 or 800 turns per minute. The moisture is driven out by centrifugal force into the outer case, from which it is drained off by a pipe.

Working the Butter.—The butter is laid on the bed of the **butter-worker** (fig. 219) and spread out to drain, covered over with a piece of muslin. If the local market demands rather a salt butter, a little dry salt may now be dredged on to the butter before it is worked. Draw the butter to the centre of the worker and commence the working slowly and carefully, continuing the operation until all the surplus water is removed.

FIG. 219.—BUTTER-WORKER.

Making up the Butter.—When sufficiently worked the butter is weighed up into pounds or half-pounds, according to market requirements, and made up into neat brick-shaped pats with a pair of **Scotch hands.** A neat pattern put on the butter greatly adds to its appearance and makes it more attractive.

Characters of Good Butter.—Well-made butter should be firm and not greasy; it should possess a characteristic texture, in virtue of which it cuts clean with a knife and breaks with a granular fracture. Theoretically, it should consist solely of the fat of milk, but in practice this degree of perfection is never attained. The legal standard for butter is that it should contain not more than 16 per cent. of water.

The amount of milk required to produce a pound of butter obviously depends on the percentage of butter-fat contained in the former. If this is 3·9, as in the

average already given (p. 552), about 26 lb. will be required. Details are given in Table XL. :—

TABLE XL.—MILK *required to make* 1 *lb. of* BUTTER.
(Ernest Mathews.)

Breed.	Butter Ratio.	Gallons.
Red Pole	30·00	3
Welsh		
Shorthorn		
Lincoln Red Shorthorn	27·50	$2\frac{3}{4}$
Ayrshire		
South Devon		
Kerry	26·00	$2\frac{3}{5}$
Dexter		
Longhorn	22·50	$2\frac{1}{4}$
Guernsey	21·00	$2\frac{1}{10}$
Jersey	19·00	$1\frac{9}{10}$

Cleaning the Churn, etc.—When the butter-making is finished, the churn and other utensils should be cleaned as follows. First wash with warm water (at temperature about 110° F.) to remove grease, and then scald with water over 150° F., wipe with a cloth, and leave exposed to dry.

CHEESE

In butter-making the object is to collect the fat only, but in cheese-making the aim is to collect the casein, with all or as much of the fat as possible, evenly distributed throughout the whole mass. This part of the milk is known as **curd**; the remaining or liquid portion is called **whey.**

Rennet is used to separate the curd, as it possesses the power of coagulating the casein present in milk. In olden times the rennet was prepared at home by placing the 'vells,' as they are termed—which consist of the fourth stomach of a calf (*see* p. 428), preferably a very young calf and one which has been fed solely on milk—in a strong brine, with a little preservative added,

and leaving to stand for a time, the liquid portion being afterwards strained and used for coagulating the milk. Concentrated preparations are now chiefly used, as they possess the advantage of constant and uniform strength, so that the quantity of rennet to be used can be accurately measured.

For the making of good cheese it is most essential to have good clean milk, and everything connected with the dairy must be kept absolutely clean.

HARD CHEESE MAKING.—The appliances consist of a jacketed cheese-vat or tub, curd-knives for cutting the curd, curd-rake for stirring the curd while cooking, curd-

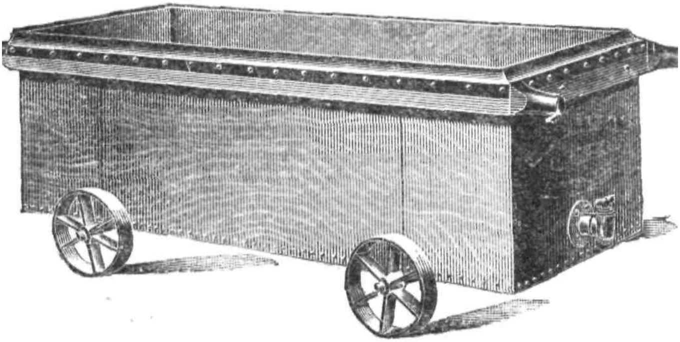


FIG. 220.—CHEESE VAT.

cooler for exposing the curd after removing the whey, curd-mill for grinding the curd, and moulds for shaping the cheese when under the press. If one cheese each day is made, one single and one double press are sufficient for cheddar-making, but for Cheshire cheese-making an extra press is required.

Cloths are required for lining the moulds or vats and for wrapping up the curd while cheddaring, and also for bandaging.

Cheddar Cheese.—The evening's milk is strained into the **cheese vat** (fig. 220). If there is a large quantity, or should the weather be close and hot, it is

advisable to effect cooling by putting cold water into the jacket and stirring the milk well. Leave till morning, when any cream should be skimmed off, warmed up to about 95° F., returned to the vat with the morning's milk and well stirred, to get it thoroughly distributed again. The mixed milk is then raised to the proper temperature for adding the rennet (generally from 84° to 86° F.), and from one to two per cent. of starter, strained through a sieve, is added (*see* p. 565). The milk is now thoroughly stirred and left for 10 to 15 minutes, when the colouring matter, or **annatto**, should be added, if the cheese is to be coloured. Annatto is added at the rate of 1 oz. to 100 gallons of milk for a slightly coloured cheese, 2 oz. to 100 gallons of milk for a highly coloured one. It must be well stirred in at least five minutes before the rennet is added, or discolouration will be the result.

The milk should now be ready for adding the rennet, and ought to contain about ·2 per cent. of acid.[1] The usual amount of rennet to use is 1 drachm of extract to 3 gallons of milk. The rennet, diluted with two or

[1] The degree of acidity in milk is determined by means of an **acidimeter,** essentially consisting of a long graduated tube or burette for holding an alkaline solution (generally one-tenth normal caustic soda) which can be run off below, and which is connected with a glass reservoir, from which it can be refilled (fig. 221). A second solution of 0·5 per cent. of phenolphthalein is employed to indicate the neutralization of the acid in the milk tested. 10 c.c. of milk are put in a small porcelain dish and a few drops of the indicator added. The alkaline solution is then gradually run into the sample, which is stirred continuously until a faint pink colour is assumed. The amount of solution used is then read on the scale in 'degrees,' which indicate the number of c.c. of solution necessary to neutralize 100 c.c. of the milk sample. The percentage of lactic acid present is obtained by multiplying this figure by 0·009.

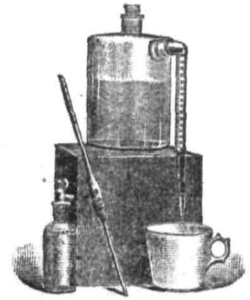


FIG. 221.—ACIDIMETER.

three times its bulk of water, is added to the milk, which is at first stirred rather vigorously for 3 to 5 minutes, and then slowly until it begins to coagulate, which will generally be in from 10 to 12 minutes. The milk is now covered over, and left to stand until the curd is ready for cutting. If it makes a clean break over the finger when inserted under and along its surface, it is firm enough to cut. Cutting is effected by a pair of **curd-knives** (fig. 222), one with vertical blades and the other with horizontal ones. The former is used first lengthwise, and is removed at the end of each cut. The curd should then be left to contract for 3 to 5 minutes, cut crosswise with the same knife, left again for about 5 minutes, and then cut with the horizontal knife both lengthwise and crosswise. The curd is now wiped from the sides of the vat, and stirred with the hand to bring it up from the bottom of the vat. If the curd is too coarse, it is cut again with the vertical knife. After leaving to stand for about 10 to 15 minutes, the mass is slowly stirred until the corners of the cubes show signs of rounding off.

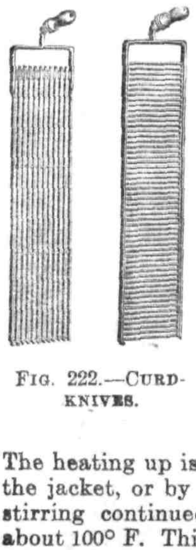


FIG. 222.—CURD-KNIVES.

The heating up is commenced by pouring hot water into the jacket, or by turning on the steam, if so fitted, and stirring continued until the temperature is raised to about 100° F. This process should take about 45 minutes. The mass should be maintained at this temperature until properly cooked, which will be in from 10 to 15 minutes, when stirring is discontinued, and the curd is allowed to settle or pitch. The curd is sufficiently cooked when it is shotty, hard, sinks quickly, has an acid smell, and answers to the hot iron test. The length of time the curd is allowed to pitch depends upon the amount of acid developed; if sweet, it may be allowed to pitch for ½ or ¾ of an hour; if it is acid, only for a short time. The whey is usually run off when the acid test

shows ·18 to ·2 per cent., or when the curd gives fine threads ¼ inch long, when a small piece is removed from the vat, pressed in the hand, dried in a cloth, placed against a bar of iron heated to a black heat, and then gently drawn away. The whey is now run off, and the curd cut up the centre and rolled to one end of the vat. A rack is put on and weighted to expel the excess of whey. In about 10 minutes it is cut up into cubes some 4 to 6 inches square, placed in a cooler covered with dry cloths, and weights placed on it. The curd is opened and turned every 20 minutes or half an hour, its outside being turned to the centre, and the weights increased until it is ready to grind. This is when it is distinctly acid to taste and smell, solid in cutting, will tear in thin layers, and attenuates from 1¼ to 1½ inches on the hot iron. It is then passed through the **curd-mill** (fig. 223), to reduce it to such a be thoroughly distributed

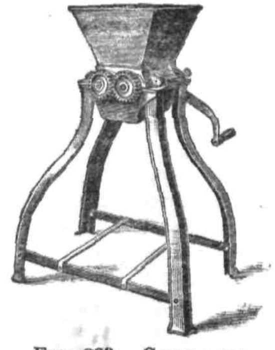


FIG. 223.—CURD-MILL.

FIG. 224.—CHEDDAR MOULD.

After grinding, the curd is weighed, and if cool enough is ready for **salting**, for which the best temperature is from 74° to 76° F. Salt is added at the rate of 1 oz. to 3 lb. of curd. The salt is well stirred into the curd, so as to ensure thorough incorporation. This usually takes about 10 minutes, and then, when the temperature is 72° to 74° F., it is **moulded**, or filled into a mould (fig. 224) lined with a cloth, being pressed tightly in with the

closed hand. The cheese is then ready for putting under the press (fig. 225). The pressure must be applied gradually, or fat will be expelled with the whey, until at the end of 2 hours we have 10 cwt. on the cheese, under which pressure it should be allowed to remain over night.

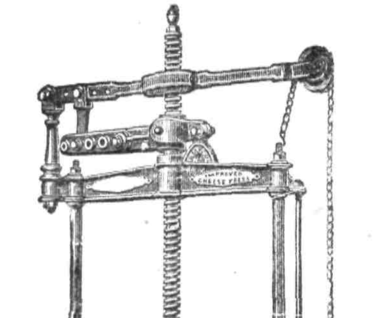


FIG. 225.—CHEESE PRESS.

The object of pressing is to consolidate the curd, and to expel the excess of whey or moisture. The day after making, the cheese is taken from the press, the cloth removed, and a clean one substituted, after which it is returned to the press, with 15 cwt. pressure. At this stage some makers bathe the cheese in water at 120° F. for one minute, which is said to improve the coat or rind, rendering it tougher and less liable to crack. The following day the cheese is again taken from the press, a coat of grease or lard put on, and its ends capped with butter muslin. It is now covered with a thin cloth, put back in the mould, and placed once more

in the press, this time being subjected to a pressure of one ton.

The next day the final bandage—either a laced or a winding one—is put on, and the cheese is removed to the ripening or curing room, the most suitable temperature for which is from 60° to 65° F. The cheeses should be turned each day until ripe, the process usually taking about four months. The length of time required for ripening can be regulated by the amount of acid allowed to develop in the curd previous to salting and vatting. The results of Mr. F. J. Lloyd's investigations into the manufacture of Cheddar cheese show that an average acidity of ·85 per cent. in the liquid oozing from the press gives slow ripening, while for quick ripening an acidity of 1·00 per cent. is required, and for very quick ripening about 1·15 per cent.

Soft-pressed Cheeses.—Among these the most noted is **Stilton,** of which the characters are as follow—(1) A drab-coloured, rough or wrinkled coat, (2) a rich and mellow, but not soapy texture (the old Stilton makers' maxim is 'Beware of chalk and beware of soap,' which means avoid hardness on the one hand, and soapiness on the other), (3) a marbling throughout the body of the cheese, due to the growth of a blue mould (*Penicillium glaucum*), commonly called painters' brush.

At least three rooms are required for the manufacture of Stilton—*i.e.*, (1) setting and draining room, (2) drying and coating room, (3) storing and curing room.

The **one-curd system** of Stilton manufacture: The milk should be perfectly fresh; that which has not lost its animal heat is most suitable. For a medium-sized cheese, take 12 gallons of milk, regulate to a temperature of 82° F., add 4 fluid oz. of starter, stir thoroughly for a few minutes. Then add 3 drachms of rennet extract diluted to about four times its bulk with water, stir well for 5 to 7 minutes, and slowly for about 3 minutes, in order to prevent the cream from rising. Cover the vessel with a cloth, and allow to remain for from 1¼ to 1½ hours, when the milk will be firmly coagulated and ready to ladle out. Ladle the curd out of the vat into straining cloths placed in a curd-sink,

or drainer. These cloths are about a yard square, holding about 3 gallons of curd each. In ladling the curd is cut into thin slices, so that the drainage of the whey is facilitated. Let the curd stand for one hour in its own whey, with the ends of the cloth just folded over. The cloths are then grasped by the four corners and lifted up, one corner being taken and wrapped round the other three, thus acting as a binder, the whole being made up into bag form. In from 30 to 45 minutes the whey is run off, the bundles or bags are tightened, and then allowed to remain in the sink for an hour longer. The whey which drains off collects and remains in the drainer with the bundles of curd. At the end of the hour the second lot of whey is run off, the bundles tied tighter, and turned over with the knot downwards, so as to hasten the drainage of the whey. The turning and tightening of the bundles are repeated every half hour, until the whey which comes from the curds shows ·18 to ·2 per cent. of acidity. At this stage the curd is turned out of the cloths into the bottom of the drainer or sink, and allowed to drain slowly until ·25 per cent. of acid is registered in the whey. Each bundle of curd should now be cut up into cubes about 4 inches square, piled up at one end of the sink to drain, and turned occasionally to facilitate the drainage of the whey. When the whey which is coming from the curd registers ·45 to ·5 per cent. of acidity, and the curd is still moist and mellow, it is ready for salting. It should be broken up by hand, and salt added at the rate of 1 oz. to 4 lb. of curd. After mixing in the salt, the curd is put into the hoop or mould (fig. 226), which should be placed on a board covered over with a piece of calico. Great care should be taken when moulding the curd to keep the centre open, and this may be done by putting the finer particles of curd at the bottom and round the sides of the mould, while the larger or coarser

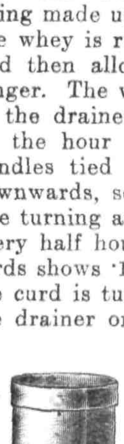


FIG. 226.—STILTON MOULD.

pieces are placed in the loosely filled centre. In filling, the curd should be firmly pressed at the bottom and lightly at the sides, but the centre must be left open or loose. The temperature of the curd at this stage should be about 65° F. When the vatting is complete, the cheese should be turned on to a fresh board and cloth and placed in the draining shelf, turned again at the end of two hours, and then left until next morning, when it is again turned. This process of turning is repeated daily until the cheese is ready for scraping. This generally takes place about the ninth or tenth day after hooping. The cheese is ready for scraping when—

(1) It leaves the sides of the hoop.

(2) It is creamy outside.

(3) It has a smell similar to that of a ripe pear.

The scraping is effected with an ordinary table knife, the object being to produce a smooth coat or surface, by filling up all holes, so that when the coat dries we get the even wrinkling which is so much desired. A bandage is now put on, and this is pinned tightly round the cheese. The hoop should be well washed, and afterwards replaced. Next day the hoop and bandage are removed, and if any holes appear in the coat of the cheese they should be filled up by scraping again. A fresh dry bandage is now applied, but the hoop is not replaced. About the eleventh day the coat begins to form, the external surface shows signs of white mould, and dry patches appear on the bandage. The cheese should now be removed to the drying and coating room, which is kept a few degrees lower in temperature than the draining room, and should if possible be arranged so as to have a current of cool moist air passing through it. This will prevent the cracking of the coat, and minimizes the loss of moisture. If the room is too dry it is a good plan to place a damp cloth over the cheese occasionally. Turn each day until the coat is firmly fixed, which generally takes about a fortnight. The cheese is then taken to the curing room, the most suitable temperature for this being from 55° to 60° F., and turned daily. It will take from 4 to 6 months to ripen. During the ripening stages the cheeses should be

brushed frequently to keep them free from the cheese mite (*Tyroglyphus siro*), an arachnid which is very destructive, especially to Stiltons. A well-ripened cheese showing innumerable blue veins, tasting rich and moist, free from acidity and excess of the flavour of mould, finds a ready sale and commands a good price. Twelve gallons of milk will produce about 10½ lb. of ripe Stilton.

SOFT CHEESES.—For the production of these small cheeses the utensils are not expensive, therefore no great amount of capital is required. As we live in the days when small holdings are becoming more numerous, there is no reason why we should not see an increase in the manufacture of these little cheeses, which are very easily made, and leave a fair margin of profit when sold. Though the demand for them at the present time is not very great, there is no doubt that the consumption would be greatly increased if they were made more widely known. For the purposes of this work it is intended to give a short description of a few of the following leading English and French varieties of soft cheeses: Cream, double cream, Cambridge or York, and sour milk cheese, of the English varieties; and Pont-l'Evêque, Neufchâtel, Coulommier, and Gervais, of the French varieties.

Single Cream Cheese (*R.A.S.E. recipe*).—This cheese is sold in England as 'Bondon.' To 1 gallon of new milk add half-a-pint of butter-milk, set at 60° to 65° F., add two drops of rennet to each quart, and stir for a few minutes. In from 24 to 36 hours the mixture will be ready to be ladled into a well - scalded huckaback cloth. Scrape down the sides of the cloth at intervals to assist drainage. In 8 to 10 hours turn the curd into another cloth and press between two boards under a weight of about 14 lb. Add 1 to 1½ teaspoonfuls of salt to curd when firm. The curd will then be ready to mould. The moulds are 2 in. in diameter and 2½ in. deep (fig. 227).

FIG. 227.—CREAM CHEESE MOULDS.

Line with grease-proof paper. One gallon of milk should make from six to eight cheeses.

Double-Cream Cheese (*R.A.S.E. recipe*).—Thick, sweet cream, without rennet. Set at 55° F. Hang up in a fine wet linen cloth, in a cool draughty place, or place over a rack. Scrape down the sides of the cloth at intervals, to assist drainage, until the cream is firm enough to mould. The moulds are made in two forms—3 in. long, 1½ in. wide, and 1½ in. deep, or 3 in. in diameter and 1¾ in. deep. Line with grease-proof paper or muslin. These cheeses are usually made without salt. One pint of thick cream will usually make three cheeses of ¼ lb. weight. Generally eaten fresh, being too rich to ripen.

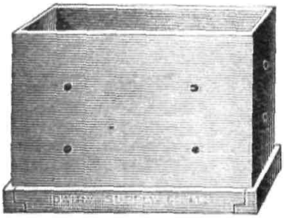


FIG. 228.—CAMBRIDGE OR YORK MOULD.

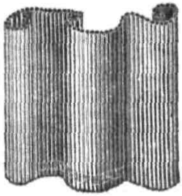


FIG. 229.—STRAW MAT.

Cambridge or York Cheese (*R.A.S.E. recipe*).—To each gallon of milk add 17 drops of rennet, and set at 95° to 98° F., and cover up for about an hour; then ladle out the curd into box-shaped moulds as carefully as possible, taking off first the thin smooth piece of curd from the surface, to be replaced on the top of the cheese when the mould is full. The moulds are of wood, 7½ in. long, 4 in. wide, and 6 in. deep (fig. 228). They are placed on straw mats (fig. 229) on stands, all of which should be thoroughly scalded before using. The cheese must then be left to drain. These cheeses do not require salt, and will be ready for use in 48 hours.

Sour Milk Cheese (*R.A.S.E. recipe*).—To 4 gallons of sour milk add 1 drachm of rennet, and set at a temperature of 84° F. Leave the milk until a little whey

appears on the surface of the curd, then ladle out into moulds placed on straw mats. Coagulation generally takes place in 4½ hours. The moulds are the same as those used for Coulommier cheeses. On the following day the upper part of the mould should be removed, the cheese turned on to a fresh mat, and the surface sprinkled with salt, while later in the same day the cheese should be turned again, and the other side sprinkled with salt. The cheese should be turned every day, and rubbed with salt twice or more until it is ripe.

Pont l'Evêque Cheese.—To make four cheeses take 3 gallons of fresh whole milk, and raise to a temperature of 95° F. Add 1 drachm of rennet, stir for 3 minutes, and leave covered over with a cloth for 50 minutes to 1 hour to coagulate. As soon as the curd will break clearly over the finger divide it into 2 in. across squares, and cut these across diagonally. In about 5 minutes ladle the curd into a coarse straining cloth and place over a curd-rack, so that the whey may escape. Tie up the cloth as described for Stilton (p. 578). Gradually tighten cloth every 20 minutes for about 2½ hours, to drain and consolidate the curd. If drainage is too slow, the curd should be cut when in the cloth, but great care should be taken not to have curd too dry, as in this case it will not mould properly. Break up curd with fingers, and fill into the moulds (fig. 230), which are usually placed on a board covered with a straw mat (fig. 229). Place firmer curd in the centre, using the softer curd for the outside. By doing so the drainage of the whey is assisted, and the finished cheese will present a smooth surface. When moulds are filled place a straw mat and a board on the top, and then turn over. In about 10 minutes turn once more, and do this about once an hour for 3 or 4 hours. Next day rub all over with dry salt, using about ½ oz. to each cheese. Turn twice daily, and remove moulds when the cheeses leave their sides, which is generally about the fifth day. In a few days' time the cheeses should be dry enough to be placed in

Fig. 230.—Pont l'Evêque Mould.

the ripening room on racks covered with straw. They will be ready for use in about 3 weeks. A good Pont-l'Evêque, when ripe, should be soft to the touch. A tough, leathery cheese is the result of too rapid drainage of the curd. When ripe, each cheese weighs about 14 oz.

Neufchâtel Cheese (*R.A.S.E. recipe*).—To 1 quart of cream add 1 quart of new milk, mix well and set at 58° to 60° F., and add 1-10th drop of rennet. This is got by mixing 1 drop of rennet with 9 drops of water, and using 1 drop of the mixture. In 24 hours the cream will be ready to be ladled out into a cloth, when it should be placed in a light wooden square frame, and left to drain for 12 hours. At the end of that time it should be gently stirred two or three times, when the cloth should be changed and the curd pressed between two boards under a weight. When the whey has been pressed out, the curd is worked smooth in the cloth with a flat trowel, and put into moulds lined with grease-proof paper. The same moulds can be used as for Double-Cream Cheese. Generally eaten fresh, being too rich to ripen.

Coulommier Cheese (*R.A.S.E. recipe*).—The quality of this cheese depends largely on the milk used for making it. To 3 gallons of milk add 9 drops of rennet, and set at 84° to 87° F. Stir for 3 minutes, and then occasionally for the first 2 hours, to prevent the cream rising. In 6 to 8 hours the curd will be ready to be ladled out in thin slices into moulds which are placed on scalded straw mats to assist drainage. The moulds are 5 in. in diameter and 5¾ in. deep (fig. 231). On the following day the upper part of the mould should be removed, the cheese turned on to a fresh mat, and the surface sprinkled with salt, while later in the same day the cheese should be turned again, and the other side sprinkled with salt. The cheese must be turned every day and rubbed with salt twice or more times until it is ripe, or it may be eaten fresh.

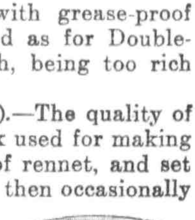


FIG. 231.—COULOMMIER MOULD.

Gervais Cheese (*R.A.S.E. recipe*).—Add 1 quart of cream to 2 quarts of new milk; mix well; set at 65° F., and add 2 drops of rennet to each quart. Stir occasionally to prevent the cream from rising, until the mixture thickens. In 7 or 8 hours the curd will be ready to ladle out into well-scalded cloths. (If a softer curd is desired, 1 drop only of rennet should be added to each quart, in which case the coagulation will be longer.) Hang the curd up to drain until it is dry enough for moulding. Scrape down the sides of the cloth at intervals to assist drainage. In hot weather it is necessary to change the cloths occasionally. Salt may be added to taste; but 1 teaspoonful of salt to 3 quarts of the mixture is about the right proportion. When firm throughout the curd is ready to mould. The moulds are $1\frac{3}{4}$ in. in diameter and $2\frac{1}{4}$ in. deep (fig. 232). Line the moulds with prepared or white blotting paper, and place them on scalded straw mats (fig. 229). Then fill them with the curd, which should be well pressed down with a spoon, and left to settle in the moulds for an hour. Three quarts of the mixture will usually make one dozen cheeses.

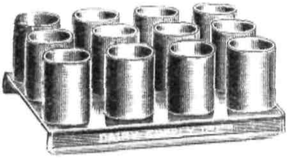


FIG. 232.—GERVAIS MOULDS.

CHAPTER XXIX.

POULTRY AND POULTRY KEEPING

FOWLS

The Origin of the Domestic Fowl.—The various breeds of fowls are believed to have originated from one wild species, the **red jungle fowl** (*Gallus bankiva*), which ranges from North India, through

South-east Asia, to the Philippines. Darwin found, in his experiments, that the domestic fowl had a tendency to revert to the wild form when crossed. He says: "From the extremely close resemblance in colour, general structure, and especially in voice between *Gallus bankiva* and the game fowl; from their fertility, as far as this has been ascertained, when crossed; from the possibility of the wild species being tamed; and from its varying in the wild state, we may confidently look at it as the parent of the most typical of all the domestic breeds—namely, the game fowl" (*Animals and Plants under Domestication*, second edition, 1882; p. 248). In colour the red jungle fowl closely resembles the Old English black-breasted red Game, but is somewhat smaller.

Classification of Breeds.—The various breeds are generally classified, according to their special qualities, as layers, table birds, and general purpose or utility. The general shape and carriage of the different breeds give us a fairly good guide as to the class to which they belong. Look at a fowl from the side, and suppose an imaginary line drawn from the front of the neck to the thigh. If the greater bulk of the body lies behind this imaginary line, laying qualities are indicated, and the fowl is classed as a layer, but if the bulk of the body lies in front of the line then it is classed as a table variety. When the body is evenly balanced on each side of the line, the bird does not excel as a layer or as a table fowl, but the two qualities are equally developed, and such a fowl is classed as a general purpose or utility fowl. The following is a list of breeds, classified according to their qualities:—

CLASS I.—Laying or non-sitting varieties:—

Ancona.	Hamburg.	Minorca.
Andalusian.	Houdan.	Redcap.
Campine.	Leghorn.	

CLASS II.—General purpose or utility varieties:—

Faverolle.	Orpington.	Sussex.
La Bresse.	Plymouth Rock.	Wyandotte.
Langshan.	Rhode Island Red.	

Gervais Cheese (*R.A.S.E. recipe*).—Add 1 quart of cream to 2 quarts of new milk; mix well; set at 65° F., and add 2 drops of rennet to each quart. Stir occasionally to prevent the cream from rising, until the mixture thickens. In 7 or 8 hours the curd will be ready to ladle out into well-scalded cloths. (If a softer curd is desired, 1 drop only of rennet should be added to each quart, in which case the coagulation will be longer.) Hang the curd up to drain until it is dry enough for moulding. Scrape down the sides of the cloth at intervals to assist drainage. In hot weather it is necessary to change the cloths occasionally. Salt may be added to taste; but 1 teaspoonful of salt to 3 quarts of the mixture is about the right proportion. When firm throughout the curd is ready to mould. The moulds are $1\frac{3}{4}$ in. in diameter and $2\frac{1}{4}$ in. deep (fig. 232). Line the moulds with prepared or white blotting paper, and place them on scalded straw mats (fig. 229). Then fill them with the curd, which should be well pressed down with a spoon, and left to settle in the moulds for an hour. Three quarts of the mixture will usually make one dozen cheeses.

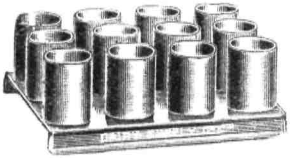


FIG. 232.—GERVAIS MOULDS.

CHAPTER XXIX.

POULTRY AND POULTRY KEEPING

FOWLS

The Origin of the Domestic Fowl.—The various breeds of fowls are believed to have originated from one wild species, the **red jungle fowl** (*Gallus bankiva*), which ranges from North India, through

South-east Asia, to the Philippines. Darwin found, in his experiments, that the domestic fowl had a tendency to revert to the wild form when crossed. He says: "From the extremely close resemblance in colour, general structure, and especially in voice between *Gallus bankiva* and the game fowl; from their fertility, as far as this has been ascertained, when crossed; from the possibility of the wild species being tamed; and from its varying in the wild state, we may confidently look at it as the parent of the most typical of all the domestic breeds—namely, the game fowl" (*Animals and Plants under Domestication*, second edition, 1882; p. 248). In colour the red jungle fowl closely resembles the Old English black-breasted red Game, but is somewhat smaller.

Classification of Breeds.—The various breeds are generally classified, according to their special qualities, as layers, table birds, and general purpose or utility. The general shape and carriage of the different breeds give us a fairly good guide as to the class to which they belong. Look at a fowl from the side, and suppose an imaginary line drawn from the front of the neck to the thigh. If the greater bulk of the body lies behind this imaginary line, laying qualities are indicated, and the fowl is classed as a layer, but if the bulk of the body lies in front of the line then it is classed as a table variety. When the body is evenly balanced on each side of the line, the bird does not excel as a layer or as a table fowl, but the two qualities are equally developed, and such a fowl is classed as a general purpose or utility fowl. The following is a list of breeds, classified according to their qualities:—

Class I.—Laying or non-sitting varieties:—

Ancona.	Hamburg.	Minorca.
Andalusian.	Houdan.	Redcap.
Campine.	Leghorn.	

Class II.—General purpose or utility varieties:—

Faverolle.	Orpington.	Sussex.
La Bresse.	Plymouth Rock.	Wyandotte.
Langshan.	Rhode Island Red.	

CLASS III.—Table varieties.

Coucou de Malines.	Game.	Indian Game
Dorking.		

CLASS IV.—Fancy or ornamental varieties:—

Bantam.	Silky.	Yokohama.

Short Description of the Common Breeds.—The leading points of the breeds—in alphabetical order—here follow:—

Ancona.—Small-bodied birds, closely resembling the Leghorns; excellent layers, non-sitters; plumage, mottled black and white; very hardy. Two varieties: the single and the rose-combed.

Andalusian.—Small bodied birds; excellent layers, non-sitters; plumage, silver-blue ground colour, laced with black; very hardy; single comb.

Campine.—Very small birds, but great layers; single combs. Two varieties: gold and silver.

Coucou de Malines.—A great table variety, having a large frame. The young birds are very hardy, grow and mature quickly, and fatten well. Plumage, barred; slightly feathered on legs. Single comb.

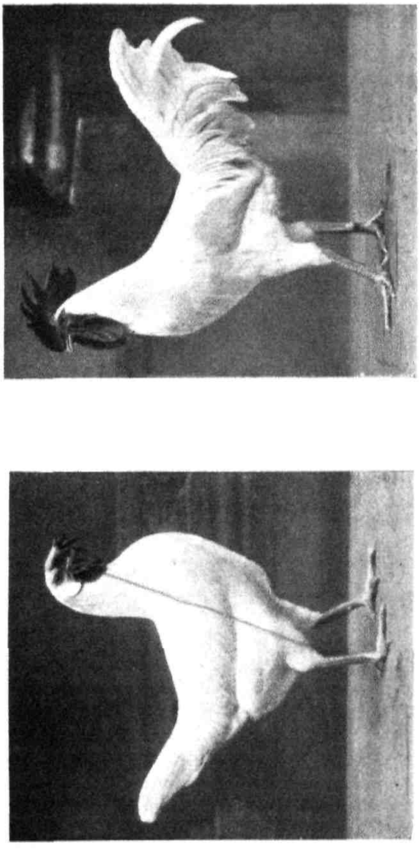
Dorking.—Large-bodied birds, with clean white legs, carrying a fifth toe. Most useful for crossing with Game for table purposes. Five varieties: dark, silver-grey, and red, with single combs; white and cuckoo, with rose-combs.

Faverolle.—Large-bodied birds, shaped like Dorkings; legs slightly feathered, and carry a fifth toe. They have a characteristic muff or beard; single comb. The young chicks are hardy and quick growing. Varieties: salmon, white, and buff.

Game (Old English).—Medium-sized bodies, with hard, close feathers; single comb; broad in breast, and carrying a fair amount of flesh of fine quality. Excellent for crossing to produce table birds. The hens are good sitters and make good mothers, but are poor layers.

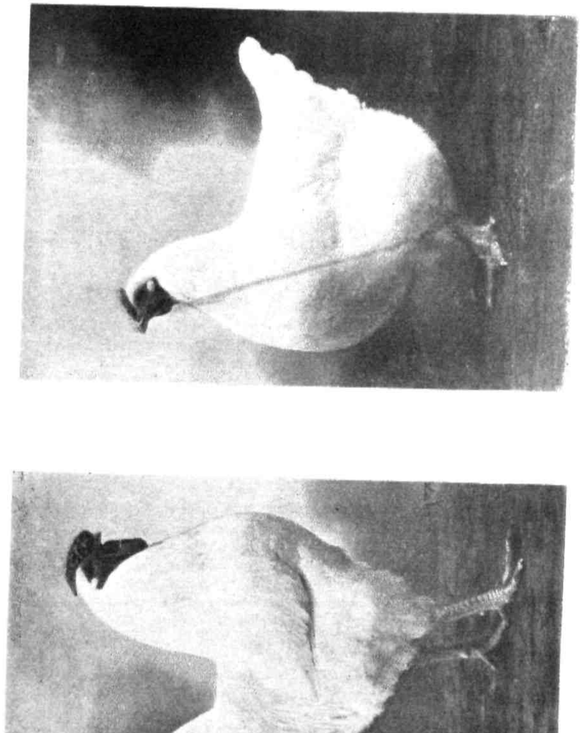
Hamburg.—Very small-bodied birds, but excellent layers, though all the varieties—with the exception of the black—lay too small an egg to be of any great market-

PLATE XVI.



1. WHITE LEGHORNS.

PLATE XVI.—*continued.*



2. White Wyandottes

value; rose-comb. Seven varieties: silver spangled, golden spangled, silver pencilled, golden pencilled, black, white, and buff.

Houdan.—Large-bodied birds, with clean legs, carrying a fifth toe; butterfly-shaped comb; plumage, mottled black and white; crested head; good layers.

Indian Game (Plate XVII., 1).—Large broad-breasted single-combed birds, carrying a large amount of flesh, and heavily-boned. Useful for crossing to produce table birds, but very poor layers.

La Bresse.—Medium-sized; single-combed; good layers of large tinted eggs, non-sitters; mature quickly, good table birds; very hardy. Varieties: black and white.

Langshan.—Large fowls, on rather long, slightly feathered legs; single comb. Fair layers of good-sized brown eggs. Two types: modern and Croad. Varieties: black, blue, and white.

Leghorn (Plate XVI., 1).—Rather small, very active birds, with yellow legs and single comb. Splendid layers, non-sitters. Eight varieties: brown, white, cuckoo, black pile, duck-wing, buff, and blue.

Minorca.—Medium-sized bodies; great layers of large, white eggs, non-sitters; rose and single combs. Varieties: black and white.

Orpington.—Large-framed birds; good layers of brown or tinted eggs and good table birds; make excellent sitters and good mothers; clean white legs. Single or rose comb. Seven varieties: black, buff, white, jubilee, spangled, blue, and cuckoo.

Plymouth Rock.—Large birds, with clean yellow legs, and heavily boned. Single comb. Fair layers of dark brown eggs, and good sitters. Four varieties: barred, buff, black, and white.

Redcap.—Small, very hardy birds. Good layers, non-sitters. Heavy rose comb; plumage red and black.

Rhode Island Red.—Of recent origin. Bodies fair size, clean yellow legs; good layers of rich brown eggs; rose or single combs; plumage cherry-red, with dark tail.

Sussex.—Medium-sized bodies, with small bone; clean white legs; single comb; good layers of tinted

eggs and good sitters; excellent for crossing with Game for table. Three varieties: red, light, and speckled.

Wyandotte (Plate XVI., 2).—One of the most popular varieties. Clean yellow legs, medium-sized bodies, rose comb. Excellent winter layers of tinted eggs, good sitters. Thirteen varieties: silver-laced, golden-laced, white, buff, buff-laced, partridge, silver-pencilled, black, black-laced, blue, blue-laced, columbian, and cuckoo.

DUCKS

The various breeds of domesticated ducks are generally believed to have sprung from the **mallard** or **wild duck** (*Anas boschas*), which is to be found all over the Continent and in America, as well as in the northern parts of Africa.

The common breeds kept in this country are:—

Aylesbury.	Cayuga.	Khaki Campbell.
Pekin.	Muscovy.	Buff Orpington.
Rouen.	Coaley Fawn.	Blue Orpington.
Indian Runner.		

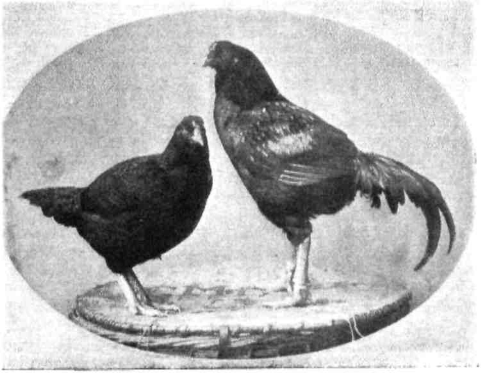
Aylesbury (Plate XVII., 3).—Large white ducks, with flesh-coloured bill and a deep keel. The ducklings are very hardy and easy to rear, and quick growers. If properly fed, will attain a good size when 9 to 10 weeks old. Not very good layers.

Pekin.—Medium-sized white ducks with orange bill. A good all-round breed. The young do not make such good weights as the Aylesbury, but become nice and plump. Very hardy and good layers.

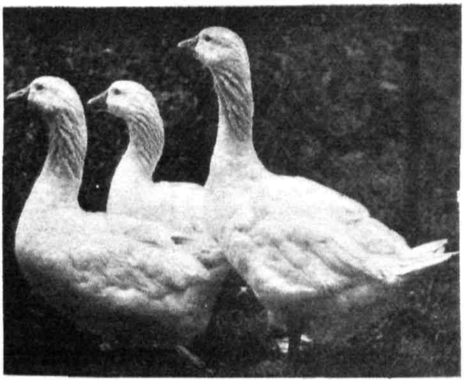
Rouen.—Both sexes resemble the mallard in colour, but greatly surpass it in size and symmetry. Not so suitable for the early markets as the Aylesbury, because they do not fatten so well; but they are excellent layers, and make great weights in the autumn.

Indian Runner.—A non-sitting breed. Excellent layers; very hardy, and great foragers. They will run over a large extent of ground, if allowed, and find the greater part of their food. Too small to be of any great value for table purposes.

PLATE XVII.

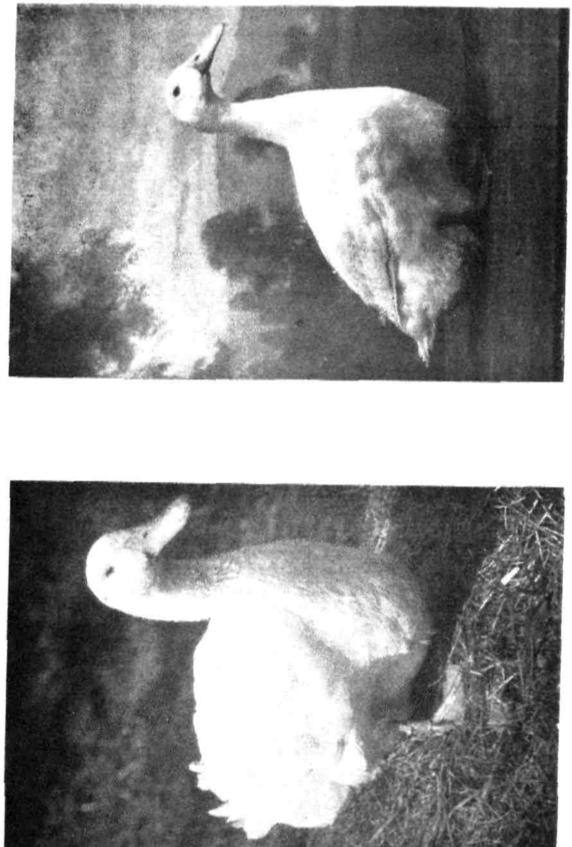


1. Indian Game.



2. Embden Geese.

PLATE XVII.—*continued.*



3. Aylesbury Drake and Duck.

Muscovy or Musk Duck.—These are not kept to any great extent, no doubt on account of their savage disposition, especially during the breeding season. They are good foragers and attain great weights.

Cayuga.—A good all-round variety; good foragers, very hardy, and quick growing. Their dark skin is the only objection.

The Coaley Fawn, Khaki Campbell, Buff and Blue Orpingtons are of recent origin, and are all well spoken of.

GEESE

Our domesticated geese have probably all originated from the wild goose or gray-lag (*Anser ferus*), which is to be found in Europe, Africa, and Asia. They generally visit this country in the winter, though some have been known to nest in the Fen districts.

Common Breeds:—

Embden. Toulouse. Chinese.

Embden (Plate XVII., 2).—An extremely hardy white breed, quick growers, and easy to rear. They are excellent for the early markets as green geese, for the goslings carry a fair amount of flesh. Mature ganders weigh up to 30 lb., and geese up to 22 lb.

Toulouse.—A steel-grey breed with deep keel, which becomes more prominent in the second year, and gives them the appearance of being much heavier than they really are. Mature ganders weigh up to 26 lb., and geese up to 20 lb. The goslings are hardy and grow well, but when growing do not carry so much flesh as the Embdens, and are therefore not so suitable for the early markets.

Chinese.—A small variety; two colours, steel-grey and white; good layers; will often commence to lay in December. When mature, the gander weighs up to 12 lb.; goose, up to 10 lb.

TURKEYS

The various breeds of the domestic turkey have probably originated from the **wild turkey** (*Meleagris gallopavo*) of North America, and, curious to say, the domestic turkey, unlike the other members of the poultry-yard, is smaller than its wild progenitor.

The **common breeds** most popular in this country are:—

The American Mammoth Bronze.	The Norfolk Black.
The Cambridge Bronze.	The White Austrian.
	The White Holland.

There are two more varieties, a buff and a blue, though neither are very largely kept.

American Mammoth Bronze (Plate XVIII.).—This is the largest of all the domesticated varieties. It is hardy, and with care can be easily reared. The adult cocks make up to 34 lb., and adult hens 20 lb.

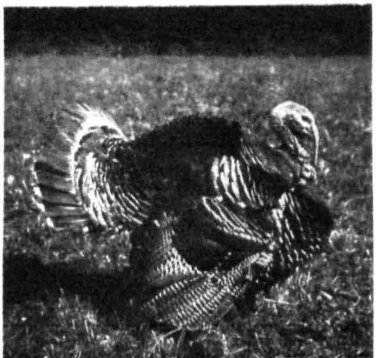
Cambridge Bronze.—This is much like the American in colour, but may be a little smaller. It has been so much crossed with the American that it is now difficult to distinguish the one from the other.

Norfolk Black.—This is often called the black turkey. It is smaller than the Cambridge, and is the hardiest and the easiest to rear.

FOWL-HOUSES

Some farmers do not pay sufficient attention to the housing of their fowls, leaving them to roost in the trees during the summer months. When frost and snow come the fowls are driven to seek shelter in the buildings, and there they become a nuisance. The cost of a suitable house is not very great, for the only essentials are dryness, good ventilation, and freedom from draughts. The number of fowls proposed to be kept must first be decided, and houses selected accordingly. For a man who has only a limited amount of land at his disposal, a **lean-to house**, with scratching-shed

PLATE XVIII.



Mammoth Bronze Turkeys.

attached, will be found most suitable (fig. 233). The **scratching-shed** should be filled to a depth of about six inches with straw chaff, dried leaves, or the like, and the corn thrown amongst it. This will cause the fowls

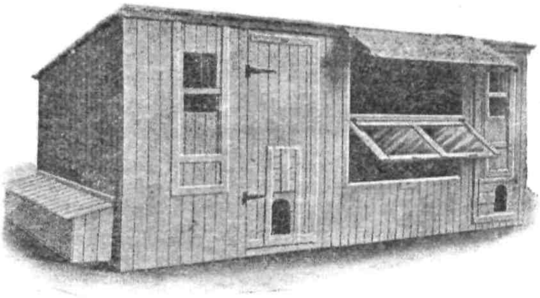


FIG. 233.—POULTRY-HOUSE AND SCRATCHING-SHED COMBINED

FIG. 234.—PORTABLE POULTRY-HOUSE.

to scratch and work for their food, and give them sufficient exercise to keep them in a healthy, profitable condition. For the farmer there is nothing to beat a **portable poultry-house** (fig. 234), as this can be moved on

to the stubble after harvest, and the fowls will be able to find their own food for some time, besides doing the fields a great deal of good. In either case it is well to bear in mind that fowls will not thrive and do so well when kept together in large numbers, about twenty to twenty-five being sufficient for one house. If the houses are kept a reasonable distance apart, the fowls will generally keep to their own batch.

The **perches** should be removable, suspended from the roof, and placed about 18 inches from the ground, allowing about 8 inches of space on the perch for each bird. There should be a sufficient number of nests to prevent the hens fighting for them, for when this occurs a number of eggs are certain to get damaged. About one nest to every three hens will be found the right proportion. There should be no draughts, but a good circulation of fresh air, and this is best obtained by having an open wire front, with sliding shutter to use when required.

SELECTION, MATING, AND BREEDING

For breeding purposes it is essential to select the healthiest stock. Choose birds which have been reared hardy, and which have never had a check in chickenhood, and these may be expected to produce fertile eggs, from which strong, healthy chickens may be hatched.

Stronger chickens are produced from hens in their second year than from pullets—*i.e.*, first-year hens—and for a high percentage of fertile eggs mate hens in their second year to a vigorous early-hatched cockerel—*i.e.*, first-year cock. When very early chickens are required the usual rule is to mate a vigorous two-year-old cock to early-hatched pullets, as the pullets come on to lay rather earlier than the hens. In the early part of the year six hens may be allowed to one cockerel in a confined run, but as the season advances ten to twelve hens to one cockerel may be allowed. When **mating ducks** the best results are obtained from two-year-old ducks mated to an early-hatched young drake, allowing

about five ducks to each drake. For **geese**, select two or three-year-old geese and mate to a mature gander; three or four geese to each gander.

When mating **turkeys** it is very essential to select good healthy stock birds, preferably two or three-year-old hens mated to a strong one-year-old cockerel, or, better still, to a two-year-old cock, allowing six or eight hens to each cock.

HATCHING AND REARING

Artificial.—With the use of an incubator it is possible to hatch the whole year round, and for hatching early table birds an incubator is almost a necessity. There are two different types of incubators:—

I. Hot water or tank incubators.
II. Non-moisture or hot air incubators.

Under suitable conditions and proper management, both types may be expected to yield satisfactory results. Makers always send out a book of instructions with each machine, and this should be well studied before attempting to start the incubator.

The Best Place to Work an Incubator.—Always select a room with an even temperature, with a northern aspect if possible. The floor should be firm, so that there will be little or no vibration. There should be good ventilation, but no direct draught. For a tank machine a platform is required, which must be firm and dead level, and about 2 feet high. Never place an incubator against a wall, but allow a space of 8 to 10 inches at the back to promote a good circulation of air.

How to Start a Tank Incubator (fig. 235).—*See that the capsule is in position, and that the needle works* freely in its tube, with its lower end in the centre of the capsule and its upper end under the milled screw. See that the lever is not damaged or bent, but allows the damper to completely cover the chimney. Slide the lead-weight as far as it will go to the *left—i.e.*, towards the

milled screw. Turn this screw till the damper rests lightly but firmly on the chimney. See that the incubator is exactly level, then place the water tray in position

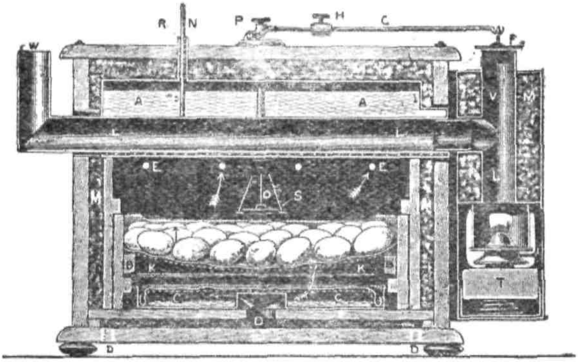


FIG. 235.—TANK INCUBATOR.

A A, water tank.
B B, movable egg tray.
C C, water tray with perforated galvanized cover and piece of canvas to allow absorption of moisture.
D D D, holes for fresh air.
E E, ventilating holes.
F, damper.
G, lever.
H, lead weight, movable.
K K, slips of wood placed under egg tray. These slips are removed when duck eggs are being incubated.
L L L, lamp chimney and flue pipe which passes through the tank.
M M M, non-conducting material, used for packing to preserve heat.
N, tank thermometer.
O, needle for communicating the expansion of capsule S to the lever G.
P, milled-head screw.
R, filling tube.
S, thermostatic capsule.
T, lamp.
V, chimney for discharge of surplus heat when damper F is raised.
W, chimney for discharge of heat after passing through tank.

and cover with canvas, but do not put any water in it. Next place the egg-drawer in position and cover with canvas.

Fill the water-tank with soft water at a temperature of about 120° F. Trim and fill the lamp, taking care not to turn the wick high enough to cause it to smoke. The machine may now be left till the heat increases and the damper rises. If the machine has been properly set, it will do so when the temperature in the drawer reaches about 98° F.

Then slide the lead weight along the lever towards the chimney about an inch, and leave for a few hours for the heat to increase; repeat at intervals of about two hours, till the temperature in the egg-drawer is 103° F., with the damper just rising off the chimney. If the incubator remains steady at this temperature for 24 hours, it is ready for the eggs. Select eggs of average size, and never use misshapen, rough, thick-shell, or very thin-shell eggs for incubating.

Mark all the eggs with a X on one side, and the breed and number of pen on the other ($\frac{RP}{20}$) for use when turning the eggs. Put the eggs in the drawer and place it in position. The temperature of the egg-drawer should be taken twice daily just before the eggs are turned. The eggs require turning twice daily, and should be aired for about five minutes each day the first week, ten minutes each day the second, and fifteen minutes each day the last week. The eggs should be tested for fertility on the seventh day, and all clear or addled eggs removed.

The eggs do not require turning after the nineteenth day, and need not be aired on the twentieth. If the eggs were fresh when put in, and the machine has been well regulated, the chicks will begin to chip the shell on the twentieth day, and should leave the egg unassisted on the twenty-first day. When the chickens are hatched they should be removed to the drying-box, and the empty shells taken out. Do not be constantly opening the drawer when hatching, as it reduces the temparature too much. Leave the chickens in the drying-box for

twenty-four hours, after which they are removed to the **foster-mother** or **rearer** (fig. 236), which has been prepared to receive them. The inner chamber of this should be about 90° F. for the first two or three days. Feed on dry chick-food and give plenty of fresh clean water and small sharp grit at first.

Chicks require feeding very often at first—say, every two or three hours—the golden rule being, 'Good food, little and often.' In a wet cold season the dry-feed

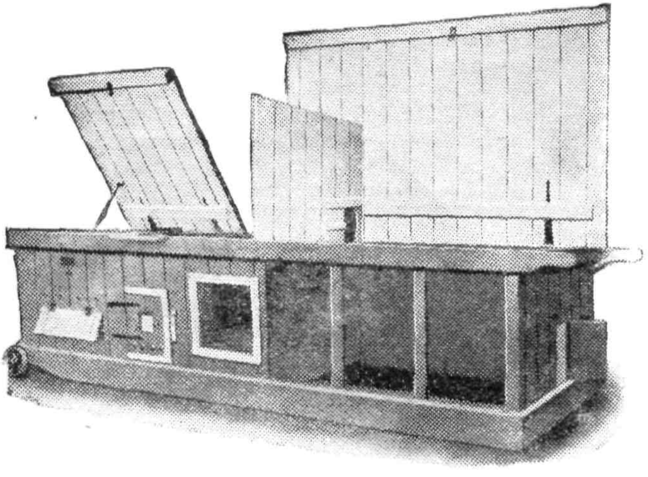


FIG. 236.—TANK FOSTER-MOTHER.

system is a great boon, as it helps to tone the system, but if the chickens are required for the early markets soft food must be given, though care must be taken not to leave any food about to get sour, as this is the common cause of bowel troubles and a large percentage of deaths in young chickens.

The temperature of the rearer should be gradually decreased as the chickens grow, until at the end of a month they should be able to do without any artificial

heat—except in very cold weather, when it is advisable to give a little heat at night.

PERIODS OF INCUBATION.

Fowl ...	... 21 days.	Goose ...	... 30 days.
Pheasant	... 24 ,,	Swan ...	... 42 ,,
Guinea Fowl...	28 ,,	Emu ...	... 42 ,,
Duck ...	... 28 ,,	Ostrich	... 42 ,,
Turkey	... 28 ,,		

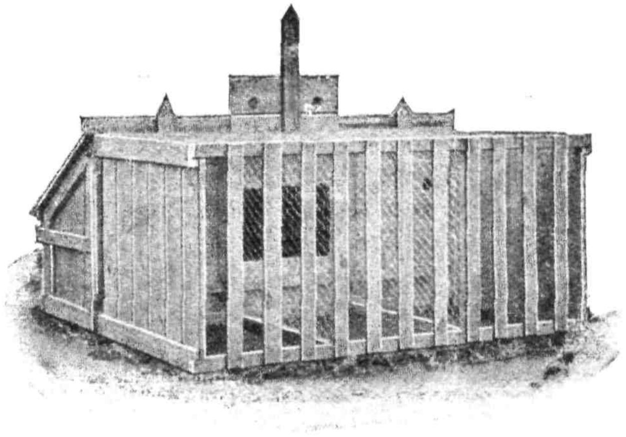


FIG. 237.—SITTING-BOX AND RUN COMBINED.

Natural Method.—Select a suitable broody hen—one of good size and docile—the short-legged varieties, such as the Wyandottes, Orpingtons, Rocks, and Old English Game being the best. The nest should be roomy—about 15 inches square, and high enough for the hen to walk off and on the nest comfortably (fig. 237). Place some mould in the bottom, and shape it out, *slightly hollow in* the centre. Cover with some soft straw or hay, and press into shape. Place a dummy egg in the nest, and put on the hen. When she has settled down the eggs may be placed under her. A hen will comfortably cover thirteen eggs, and this is the usual number. It is a good plan

to sit two or three hens together, and test the eggs at the end of the first week, when perhaps two of the

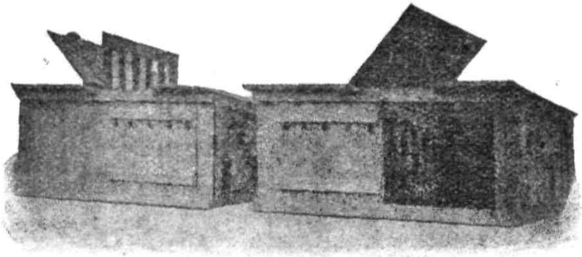


FIG. 238.—HEN COOP.

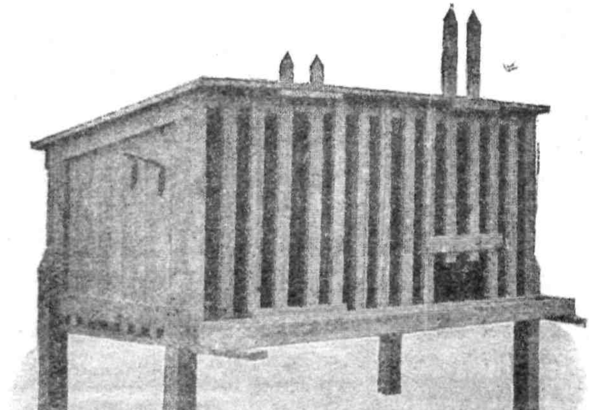


FIG. 239.—FATTENING COOP.

hens would take all the fertile eggs and the third could be started with a fresh batch.

They should be let off to feed each day, and should have only grain, wheat, or maize, and plenty of fresh water and grit: a dust-bath should always be supplied when possible. Do not meddle too often with hens when hatching, for they are apt to get peevish, and will crush the chickens as they are just hatching. Before removing to a coop (fig. 238) the hen should have a good feed of corn, and when the chickens are fed she will call them to the feed instead of taking it herself

Feeding Table.—*First Week:* Dry chick-feed every three hours, and a good supply of water and fine grit.

Second and Third Weeks.—Scalded biscuit meal mixed dry with Sussex ground oats for the first meal and at midday, and dry chick-food the second and last meals

Fourth to Tenth Week.—Sussex ground oats mixed to a crumbly state with skimmed milk (two feeds each day), and grain (two feeds).

After Ten Weeks.—Three feeds each day will be sufficient (two feeds of soft food, with grain at night). As chickens need a high albuminoid ratio, a little flesh food or green bone may be added with advantage. After four months old feed as stock birds for pullets. The cockerels, unless intended for stock, should be fattened.

Fig. 240.—Cramming Machine.

A, food reservoir.
B, pump cylinder.
C, spring for bringing foot pedal and piston back.
E, piston rod.
K, nozzle or food tube.
M, screw for regulating quantity of food delivered at each stroke of the piston.
O, foot pedal.

Fattening.—When 12 to 14 weeks old the cockerels should be separated from the pullets and placed in fattening pens (fig. 239), where they are fed on soft food. The food which gives the finest quality of flesh is Sussex

ground oats mixed with skim or separated milk; if the milk is sour so much better. The food should be given rather moist, as no water is supplied whilst fattening. When very prime birds are required they should be crammed (fig. 240). The same kind of food is used, with sometimes a little additional fat, and the birds are crammed twice each day at equal intervals of time, just giving them as much as they can digest. Ten or fourteen days' cramming is as much as they can stand, and they should be killed off at the end of this time, or they will lose weight.

Ducklings.—These only require a little heat for the first ten days or two weeks in cold weather. The food should consist of barley meal, pollards, and maize meal, mixed to a crumbly paste with milk for the first six weeks; the remaining four weeks they should be fed on rice cooked in milk and mixed dry with pollards and oatmeal. Sufficient water should be supplied for drinking purposes only, and some grit should be placed in the bottom of the drinking vessel. They should have plenty of green food and boiled vegetables, as this tends to keep them healthy and is cooling to the blood. They should be ready to kill at ten weeks old—that is, before they begin to moult. It is a good practice to allow them to swim in a pond about two days before they are killed, so that they may clean their feathers.

Geese.—Young goslings require very little artificial food, as they consume a considerable quantity of grass. A little boiled wheat mixed dry with barley meal is a good food to give them a start. They should be placed in a large roomy coop with a run in front for a few days. The coop should be bottomless and placed in the shade, for the young goslings do not thrive so well when exposed to the direct rays of the sun. They should not be allowed to swim for the first two or three weeks, unless the weather is very warm.

If required for the Michaelmas trade, they should be kept in good condition, and should have a morning meal of barley and maize meal, and oats at night; but when required for the Christmas trade, one feed of corn

in the evening is all they require to keep them in good growing condition. They should never be allowed into a stream, as fighting against the current when going up-stream tends to harden the muscles and makes them very tough.

Turkeys.—For the successful rearing of young turkeys it is essential to have good, clean, well-drained land, with short grass, large, well-ventilated houses, and good sound food.

The first feed should be given when they are twelve hours old, and should consist of hard-boiled eggs, chopped fine and mixed with breadcrumbs. This should be dropped right in front of the young birds, so as to attract their attention. Skim milk should be given to drink, and plenty of chopped green food, such as onions and dandelions. After the first week discontinue the egg food, and gradually change the food to ground oats and pollards mixed to a crumbly state with sweet skim milk, and plenty of green food. They require very close attention during the first two months, and must be protected from wind and rain till they have 'shot the red,' which is the appearance of the red growths on the head. After this they become much hardier, and their appetites increase enormously. They must be kept growing, and given a good range, for they are splendid foragers. About a month or five weeks before Christmas they should be placed in a dry shed and fattened, the food to consist of barley meal, ground oats, and pollards, mixed to a paste with skim milk for morning feed, and oats and barley and wheat in the evening. They should always have a good supply of sharp grit and fresh clean water.

KILLING AND DRESSING

Killing.—There are many ways of killing a fowl, but the most humane one, as well as the quickest and cleanest, is to dislocate its neck, as no blood is seen. The bird should be taken by the legs in the left hand, which can grasp the ends of the wings also; take the head in the right hand. Place the legs against the

left hip and the head over the right thigh. Draw the fowl to its full length, and at the same time turning the head suddenly backwards, the neck becomes dislocated just below the junction with the head. There will be a certain amount of muscular contraction and some fluttering, but if the operation is properly carried out there is no pain. Plucking should commence as soon as the bird is killed, for a bird is much easier to pluck while warm. When this operation is completed, the birds are placed on a **shaping-board** (fig. 241) breast downwards, with a board and a weight placed on their backs, and left till cold. This greatly improves their appearance, making them look much plumper than they did before.

FIG. 241.—SHAPING BOARD.

Dressing and Trussing.—All that is required is a good knife, a trussing - needle (about 10 inches long), and some fine strong string.

The birds should be singed to get rid of the hair, using straw or grease-proof paper, so that there will be no smoke to discolour the skin. They are then wiped over with a dry cloth.

Lay the chicken on its breast, take the skin where the neck joins the body in the thumb and first finger of the left hand, and make a transverse cut, exposing the neck. Cut off the neck just where it joins the body, leaving about two or three inches of skin in front; now turn the bird breast upwards, and take out the crop. Insert finger in Λ-shaped opening, and, loosening all the internal organs which can be reached, turn the bird on to its breast, stern upwards, and make a cut between the tail and the vent and an angular cut on each side of tail (this prevents the skin splitting when the bird is being drawn). Insert the finger and find trail, pass the knife under loop, and cut off the vent.

Loosen the fat from the gizzard, and then, by taking hold of this and drawing gently, the whole of the intestines, with the liver, heart, and lungs, will come away in one mass. Cut off the extreme tips of wings and feet, and nick the skin in front of and an inch above the hocks. Place the needle through the leg and body and out through the leg on the other side, and back through the wing over the back, and through the wing on opposite side; pull tight and tie. Pass the needle through body at end of back near the tail over the leg, through the skin under the breastbone, and over the other leg, and tie tightly. Smooth the fowl over, and the operation is complete.

Ducks are generally killed by breaking the neck, as described for the fowl, plucked, singed, and wiped over with a cloth.

Cut off the neck where it joins the body, leaving about two inches of skin to fold over stump. Then place the bird in a basin and pour boiling water over the breast and feet (this tightens the skin and makes the bird look a great deal plumper). Lift the bird out of the water and wipe dry, then strip the hard outer skin off the legs and feet and remove the nails. Place the bird on its back, and with the second finger of the right hand loosen all the internal organs (as in the case of the fowl). Turn the bird round, make a transverse cut below the tail, insert finger and find trail, which is cut off.

Loosen the fat from the gizzard, and then, by taking hold of the gizzard and pulling gently, the whole of the intestines, with the liver, heart, etc., will come away in one mass.

Cut off the wings at the first joint, stitch the neck skin over stump and tie the wings across the back with tape. Press the feet inwards and downwards, so as to bring them under the thighs, and hold them in position. Then place the giblets—*i.e.*, the neck, heart, liver, gizzard, and wings—into the body of the bird. Pass the tail through the hole where the vent is, cut out and tie the legs across the back with tape. Lay any fat which is taken out of the bird over the breast, and place on a slate slab to cool for a few hours, when it

will be ready for market. Never pack ducklings whilst they are warm, because they discolour so quickly. They should always be allowed to get cool and firm before packing.

Geese.—The best method of killing a goose is to give it a sharp blow on the head with a stick to render it unconscious, and then cut across the base of the skull with a sharp knife.

Geese are dressed in the same manner as described for ducks.

Turkeys.—The best method of killing a turkey is to fasten its legs with a strong cord, and by this cord suspend it to a beam head downwards at a convenient height for the operator to pass his left arm round the bird's body. Take its head in the right hand, extend its neck to full length, and give a strong jerk downwards, at the same time turning the head upwards. The neck is dislocated just below the junction with the head, and death will be instantaneous. There will be some muscular contraction, but no further pain.

Turkeys are dressed in the same way as fowls, though it is usual to remove the merrythought, so as to allow of a better cut of breast and forcemeat when carving.

MARKETING OF EGGS

The National Poultry Organisation Society was formed in 1898 for the purpose of encouraging the poultry industry in this country, and of establishing a system on strict business lines by which farmers and others may market their poultry and eggs in accordance with modern requirements. Depôts are formed, and the members are supplied with a stamp with which all eggs are marked, and any bad or stale eggs can thus be traced. The eggs are collected or delivered at the depôt at least three times a week, so that freshness may be guaranteed. At the depôt every egg is tested for freshness and quality, and every egg passing the test is branded with the trade-mark of the Society, graded, packed, and despatched without loss of time to the great centres of population.

The results of the adoption of this system has been to improve the quality of produce due to more rapid marketing, and to greatly enhance the returns obtained by the producers.

PRESERVATION OF EGGS

Eggs for preservation should be treated as soon as possible after they are laid, or as soon as they have cooled. Infertile eggs are likely to keep better than fertile ones.

The best months for preserving eggs are March, April, May, and June, and these are the months when the eggs are most plentiful.

The best results are obtained when the eggs are stored in a cool place.

The following are the common methods of preserving eggs:—

I. Water glass (silicate of soda).
II. Lime water.
III. Salt.
IV. Fat or Butter.

Water-glass is now one of the most popular methods of preserving eggs. A concentrated solution may be purchased at all chemists and stores, and it is very easy to prepare. A 10 per cent. solution is generally employed, though experiments have proved that a 5 per cent. solution gives very good results. It will mix better with hot water, but the solution must be quite cold before putting in the eggs. Take care to see that all the eggs are sound when putting in. If any are cracked, they may spoil the whole batch. See that the solution covers the eggs to a depth of about 2 inches.

Lime Water.—This is one of the oldest methods of preserving eggs, and it has the advantage of being very cheap. One gallon of lime (slaked) is mixed with a quart of salt and added to five gallons of water, and thoroughly mixed and allowed to stand for a few days. The clear liquid is drawn off, and this is poured over the eggs so as to completely cover them. A cloth is

placed over the top, just touching the water, and into this cloth some fresh slaked lime is put, so that if the lime in the solution loses its effect, more can be taken up.

When the eggs are taken out of the solution they require very careful handling, as the shells are very brittle; and they are also very rough.

Salt.—Eggs can be preserved in salt by placing about two inches of salt in a jar or case and laying the eggs in the salt with the broad end down. Cover with a 2-inch layer of salt, and another layer of eggs, and so on, till the case is full. The one objection to this method is the increase in the air space, which gives the eggs the appearance of being stale.

Greased Eggs.—This method consists of coating the eggs with a thin layer of fat or butter. Take a small piece of butter in the palm of the left hand, and with the right hand turn the egg round several times, so that it gets a thin coat of butter all over the shell, thus closing the pores and preventing evaporation of moisture. The eggs are then stored, with the broad end downwards, on shelves. Care must be taken that the butter is of good flavour, or the contents of the egg will become tainted.

DISEASES

It is impossible in this work to describe fully the symptoms and treatment of all the diseases to which poultry are subject, therefore only a few of the more common ones are dealt with. Disease may be easily checked if taken in its early stages, and it should be the duty of the attendant to keep a look-out for any bird which may appear out of condition. Any such bird should be taken in hand and treated at once.

Catarrh.—One of the commonest diseases in poultry is catarrh, or cold in the head. Symptoms are sneezing and a thin watery discharge from the nostrils. The causes are damp or exposure, sudden changes of weather, overcrowding in badly-ventilated houses. **Treatment.**—Warmth is the most essential thing. Place the bird in

a dry place, feed on soft nourishing food, to which a little powdered ginger may be added, and put a little sulphate of copper in the drinking water, using glass or earthenware vessels.

Roup.—If colds are neglected they may develop into roup. The discharge from the nostrils becomes thicker, with an offensive odour, the face becomes swollen, and one eye may be completely closed. There is loss of appetite, and the bird mopes about. **Treatment.**—The same as for cold—warmth, and sulphate of copper in the drinking water. The mouth and face should also be washed with permanganate of potash.

Crop-bound.—Caused by careless feeding. Pea-shells or pods, cabbage-leaves, etc., are common causes. The crop becomes packed with food which cannot pass, and it hangs down like a bag. If the trouble is discovered early the cure is easy. **Treatment.**—Pour a little warm water down the throat and gently work the crop with the hands. This will cause the food and fluid to mix, and when the mass is broken up the chances are that it will pass away. If the kneading process is not effective an operation becomes necessary.

Gapes.—*Mostly affects young chickens from one to* three months old, and is caused by a parasitic worm, which affects the windpipe and makes the chicken gasp for breath. Symptoms: repeated gaping, shaking the head and coughing. At the same time the chicken runs backwards and droops its wings. **Treatment.**—Remove chickens to fresh ground, and give a good dressing of lime. A small feather stripped of all except the tip, dipped in turpentine or eucalyptus oil, and pushed down the windpipe, will sometimes effect a cure. Any chickens which die should be burnt, to destroy the worms and prevent further spreading.

Liver Disease.—This is one of the most dreaded diseases, and is contagious. Symptoms: The birds mope about and become thin and poor. The comb becomes shrivelled and turns a purplish colour. The excreta are of a light yellow colour. **Treatment.**—Remove to fresh runs. Any bad cases should be killed and burnt. All the houses should be thoroughly disinfected. Give

doses of Epsom salt, and feed very sparingly. Put a fair amount of lettuce or dandelions in soft food. Administer a liver pill occasionally.

Scaly Leg.—Symptoms: Rough scales on shanks. Causes: Keeping the fowls on a very dry run, such as dry ashes, or over-heating food. This allows the entry of a parasitic mite (*see* p. 645). **Treatment.**—Wash the bird's legs with warm water and soap and dress with paraffin or sulphur ointment. Wash and disinfect the perches.

Egg-bound.—When hens make frequent and prolonged visits to the nest without any result and appear distressed through prolonged straining, it is generally a case of egg-bound, which may be caused from over-fatness or from an abnormally large egg in the oviduct. **Treatment.**—Take the hen and hold her with the vent over a vessel containing hot water for a few minutes, and afterwards pour a little oil into the vent. Place in a quiet place for a few hours, when she will probably get rid of the egg. Avoid all fat-forming foods, and give a little Epsom salt in drinking water.

CHAPTER XXX.

HARMFUL AND BENEFICIAL ANIMALS

The practice of agriculture upsets the balance of Nature by cultivating plants and domesticating animals intended for the maintenance of mankind, but also adding locally to the supply of food upon which wild forms, including parasites, can draw. Many of these forms are consequently reckoned as 'pests,' or harmful animals, the natural enemies of which may be considered 'beneficial' from the agricultural standpoint. It is clearly necessary that the farmer should know his friends from his foes, and the object of the present chapter is to enable him to do so.

Groups of Animals.—We have already considered domesticated members of two of the classes of Backboned Animals—*i.e.*, Mammals and Birds—which also include wild forms of importance. The other backboned classes are Reptiles, Amphibians, and Fishes. British **Reptiles,** including several lizards and three kinds of snake, are of no particular importance. **Amphibians** are creatures with soft slimy skins, and begin life as aquatic tadpoles. They comprise frogs, toads, and newts, all of which devour insects and other small creatures, and are decidedly beneficial. Toads, in particular, destroy large numbers of snails and slugs in gardens. **Fishes** are of no agricultural importance, except as a source of manure or artificial feeding stuff.

The great group or subkingdom of MOLLUSCS or SHELL-FISH includes animals of which the bodies are not divided into rings or segments, nor are they provided with limbs. A protective shell is usually present. The classes including cuttle-fishes and bivalve molluscs (cockle, oyster, mussel) require no especial mention, although it may be noted that some limestones are partly composed of their shells; but the class of **Gastropods** includes land snails and land slugs, among which are notorious pests. The damage done by them to various cultivated plants is effected by means of a rasping organ situated in the cavity of the mouth. Probably the grey field slug (*Limax agrestis*) is the most objectionable, and this is usually destroyed by dressings of slaked or unslaked lime, or a mixture of salt and soot. One application is not sufficient, as the body of the pest is able to exude a large amount of protective slime. Fortunately, snails and slugs have many natural enemies among the small wild mammals, birds, and amphibians.

A few slugs (species of *Testacella*) are beneficial, because they live underground and destroy various pests, such as other slugs, snails, and insect larvæ. They may be recognized by the presence of a minute conical shell on the tail end.

The vast group of JOINTED-LIMBED ANIMALS or ARTHROPODS includes a great variety of forms, in which the body is divided into rings or segments, and possesses

a varying number of jointed limbs, some of which are modified into jaws. One class—that of **Crustacea**—chiefly comprises aquatic forms, such as lobsters, crabs, prawns, and shrimps, and therefore is of no particular agricultural importance. The **woodlice**, however, are land crustaceans, which damage fruit and mushrooms. They are easily trapped by means of hollowed-out potatoes or apples.

The remaining classes of Arthropods—(1) Insects, (2) Arachnids (scorpions, spiders and mites), and (3) Myriapods (centipedes and millipedes)—are all of importance, and require detailed treatment.

SEGMENTED WORMS or ANNELIDS include earthworms and leeches. The beneficial action of the former has already been described (p. 9).

There are two important groups of unsegmented worms, in which the body is not divided into segments —*i.e.*, ROUND WORMS (NEMATHELMIA) and FLAT WORMS (PLATYHELMIA), the latter comprising Flukes (Trematoda) and Tapeworms (Cestoda). These groups include dangerous and undesirable parasites, and more will be said about them in the sequel.

The lowest group or subkingdom of animals is that of ANIMALCULES or PROTOZOA, unicellular forms of minute or microscopic dimensions, which live almost everywhere. Some of the parasitic species will be mentioned at the end of the chapter.

The more important of the above groups of animals will now be treated in greater detail.

MAMMALS

The wild species of most agricultural importance are included in four orders—(1) Flesh-eating Mammals (Carnivora), (2) Gnawing Mammals (Rodentia), (3) Insect-eating Mammals (Insectivora), (4) Bats (Chiroptera).

FLESH-EATING MAMMALS (CARNIVORA).—The **fox** (*Canis vulpes*), though destructive to game-birds and poultry, destroys various pests, such as hares, rabbits, field voles, and insect larvæ.

The badger, stoat, weasel, and polecat all belong to the same family (**Mustelidæ**). The **badger** (*Meles taxus*) is a rather clumsily-built animal, which lives in a burrow and is of nocturnal habits. Its average length is between 2 and 3 feet. The food is of mixed nature, including a great variety of vegetable substances and small animals. A certain amount of damage is done to game, but the badger is predominatingly beneficial, destroying great numbers of voles and other rodents, and also many insect pests, wasp-grubs being especially relished.

The **stoat** (*Putorius erminea*) is about 16 inches long (including the 4-inch tail), and is distinguished by its narrow body and short legs, enabling it to forage among undergrowth and in other confined spaces. The summer coat is brownish above and white below, with a black tip to the tail. In winter it turns more or less white (especially in the north), but the end of the tail retains its colour. This winter coat is the source of the valuable fur known as 'ermine.' Stoats are rapacious nocturnal animals, which effect much destruction among game and poultry, though this is largely compensated by the killing of large numbers of vermin.

The **weasel** (*P. vulgaris*) is a good deal smaller (10 inches long, including the 2-inch tail) and slenderer than the stoat, and does not undergo the same marked colour change in winter, being always reddish-brown above and white below. Its habits are much the same as those of the stoat, but it is far more bloodthirsty, which enhances both the good and harm done.

The **Polecat** (*P. fœtidus*) is a rare animal of much larger size than either of the two preceding forms, and of similar habits. It is dark brown in colour, with an intermixture of yellow woolly hairs. The **ferret** is a domesticated variety of this species.

Gnawing Mammals (Rodentia).—The mammals of this order found in Britain are generally small or very small. They mostly feed entirely on vegetable substances, though rats and mice are omnivorous. The most striking characteristic of animals belonging to this order is the peculiar nature of the front teeth (incisors), which are adapted for effective gnawing. Of these teeth there

are two above and two below, their edges being sharp and chisel-shaped. They are maintained in this condition by a process of unequal wear, their front surfaces being coated with a very hard substance (enamel) which resists attrition to a much greater extent than the softer ivory (dentine) behind it. When an incisor is pulled from the jaw, it is found to be of great length and not to taper into a fang. These teeth, in fact, grow continuously throughout life, and constant gnawing is necessary to prevent them from becoming too long. The joint between the lower jaw and the skull is of such a nature as to permit a certain amount of forward and backward movement, thus enabling the incisors to be used as chisels or gouges. Three families are of importance, as the animals they include are all more or less injurious to agriculture.

Hares and Rabbits (Leporidæ).—These are larger than the members of the other two families, and are distinguished by the presence of a second very small pair of upper incisors behind the large ones. They are, in fact, teeth which are undergoing degeneration.

The **hare** (*Lepus europæus*) and **rabbit** (*L. cuniculus*), though much alike in structure, differ a good deal in their habits. The former is solitary and does not burrow, and the young are born with their eyes open, being able to shift for themselves very early. The rabbit, on the other hand, is gregarious, lives in burrows, and gives birth to blind, helpless young. Its mode of life makes it more difficult to keep down than the hare, and it is also much more prolific. Both species are very destructive to young crops and garden plants. They also kill young trees by gnawing the bark. The methods of hunting down these rodents are familiar to all, and they can be kept out by the use of wire. Under natural conditions their numbers are prevented from undue increase by such natural enemies as stoats, weasels, and birds of prey, hence if these checks to increase are unmercifully persecuted the result can easily be foreseen.

Rats and Mice (Muridæ).—These animals are distinguished by a pointed snout, prominent ears, and long scaly tail. The old **black rat** (*Mus rattus*) is now a scarce

animal, except locally, having been supplanted by the larger and fiercer **brown rat** (*M. decumanus*), which is said to have been introduced into this country in the eighteenth century. Rats eat almost everything, and cause serious loss to the farmer. They are extremely prolific, producing several litters a year, with as many as eight young to a litter. The serious disease trichinosis (p. 648) is widely disseminated by them, and the fleas with which they are infested are responsible for the distribution of the germs of Oriental plague.

In spite of the wholesale means adopted to keep down the number of rats, involving the use of ferrets, traps, poisons, and several kinds of bacterial preparations known as 'virus,' only very partial success has so far been attained. Nothing but concerted action in all parts of the country is likely to give substantial results. The wanton and indiscriminate slaughter of birds of prey, and the war waged against stoats and weasels, are largely responsible for the enormous increase in the number of rats, and this is also true as regards mice and voles.

Mice include the **house mouse** (*Mus musculus*), which is the cause of much damage out of doors, as well as in buildings, the **long-tailed field mouse** (*M. sylvaticus*), which devours grain, and the little **harvest mouse** (*M. messorius*), which also destroys a certain amount of grain. The two last species, however, destroy a good many injurious insects and their larvæ. The numbers of mice are kept down by trapping, poison, and virus.

Voles (Arvicolidæ).—These animals are often mistaken for rats and mice, but can easily be distinguished by their rounded snouts, small ears, and short, often hairy tails. They are purely herbivorous. The most troublesome species is the **short-tailed field-vole** (*Microtus agrestis*), which sometimes multiplies so rapidly as to become a serious pest (fig. 242). It is a burrowing form, and destroys all sorts of cultivated plants, including young trees, by gnawing through their roots. Poison and virus are used for the destruction of voles, and in some cases large numbers have been trapped in trenches about 2 feet long, constructed on the pitfall principle,

narrow above (about nine inches across) and sufficiently deep (18 inches), with unclimbable sloping sides diverging downwards, so as to make the floor of the trench about double the breadth of its opening above. Successive trenches should be dug 30 yards apart.

Insect-eating Mammals (Insectivora).—These include small or diminutive animals, which feed not only on insects, but many other small creatures, such as slugs and worms. Not only are the front teeth pointed, but

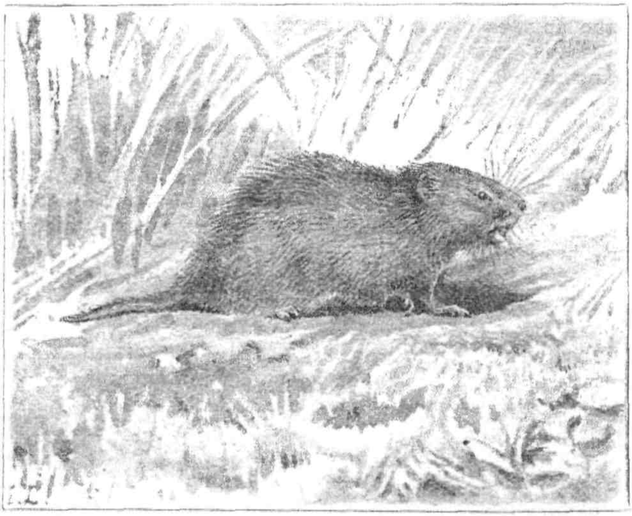


FIG. 242.—SHORT-TAILED FIELD-VOLE (*Microtus agrestis*).

the grinders are studded with sharp points, an obvious adaptation to the nature of the food. The snout is long and narrow. They include the hedgehog, the mole, and the shrews.

The hedgehog (*Erinaceus europæus*) is the largest of our native species, and more omnivorous in its diet, which includes fallen fruit as well as insects, slugs, snails, frogs, small reptiles, and mammals. It does some harm by

devouring the eggs of poultry and game birds, with an occasional chicken or duckling, but is predominatingly beneficial.

The **mole** (*Talpa europæa*) is well adapted for an underground life and devours enormous numbers of worms and insect larvæ. Although its molehills disfigure lawns and pastures, this animal does far more good than harm.

Shrews or **shrew-mice** are very small mammals which destroy large numbers of worms, insects, and slugs, so that they are decidedly beneficial. They include the **common shrew** (*Sorex vulgaris*), the **lesser shrew** (*S. minutus*), which is the smallest of British mammals (about 2 inches in length), and the **water shrew** (*Crossopus fodiens*).

Bats (Chiroptera).—Bats are closely related to the members of the last family, differing chiefly in the possession of flying organs, consisting of a fold of skin supported by the four greatly elongated fingers. The thumb is short and hooked. There are over a dozen native British species, all of which are entirely insectivorous, catching their prey on the wing, and materially assisting in keeping down the numbers of many noxious forms. They are therefore purely beneficial, and it is a great mistake to molest them.

BIRDS

Birds have undoubtedly descended from reptilian ancestors, but in the course of many ages have become specialized on lines of their own, so that they now form a well-defined class. The oldest known extinct bird possessed a long tail and numerous conical teeth, but in existing forms the tail has been greatly abbreviated for the support of quill feathers, and the teeth have entirely disappeared, their place being taken by horny sheaths, which cover the jaws. The organs of circulation in birds are extremely efficient, one consequence being a very high body temperature (varying from 100° to 110° F. in different cases), which is associated with restless

energy. The structure of a bird embodies, as might be expected, a large number of adaptations to flight, and even birds that are now unable to fly (ostrich, penguin, etc.) have descended from ancestors which possessed that power.

The **wings** are quite unlike the flying organs of bats, for the digits are reduced to three, and there is a good deal of fusion among the bones of the hand and forearm, in order to give a firm support to the quill-feathers (*remiges*) they bear, and which are used as organs of propulsion. The tail-quills (*rectrices*) serve for steering.

The characteristic **feathers** have no doubt been derived from reptilian scales by increase in size and modification in structure. Those which clothe the body entangle a large amount of air, and prevent the escape of heat.

The absence of teeth in birds is compensated, especially in those which devour hard substances, by modifications of the digestive tube. The gullet usually expands into a pouch or **crop**, which serves as a temporary receptacle for food, and the stomach is divided into a **chemical stomach** (*proventriculus*), by which gastric juice is secreted, and a powerful muscular **gizzard** with tough lining. The gizzard, aided by small stones, etc., which are swallowed, acts as a sort of mill. The **beaks** and **feet of** birds present a large number of modifications in different cases, which have reference to the mode of life and nature of the food.

It is a familiar fact that birds (like reptiles) **lay eggs**, and hatch them out by incubation. The young at hatching are either able to run at once from the nest (fowl, plover) or are helpless nestlings, which require tending for some time by the parents. Harmful birds belonging to the second category are obviously more easy to deal with than would otherwise be the case.

Relation of Birds to Agriculture.—Whether a particular bird is harmful or beneficial to agriculture will obviously depend on the nature of its food, for if this consists entirely or mainly of such things as grain the bird is manifestly harmful, while the reverse is true when the food is entirely or chiefly composed of injurious

insects or the like. Difficulties arise, however, when the diet is of mixed kind, as is frequently the case, though fortunately it can be said that the large majority of birds are useful and should not be molested. In many cases extended and accurate investigations are required, the only sound method being the expert examination of the contents of the crop.

It is necessary to bear in mind that the habits of a particular bird vary at different seasons and in different localities, so that hasty conclusions should be avoided, and it is desirable to give a supposed culprit the benefit of the doubt, should such exist. It must also be remembered that the habits of some birds appear to be altering, at least locally. At one time, for example, it was probably correct to consider the starling as purely beneficial, but in some counties it has of recent years undoubtedly acquired the bad habit of attacking various kinds of fruit.

The limitations of space prevent full consideration of British birds, and it must suffice to classify the common species according to their bearing on agriculture.

Birds Entirely or Mainly Beneficial.—Here may be included the game birds (pheasant, partridge, etc.), the gulls, the rails (corncrake), and the plovers. With the possible exception of the sparrowhawk, which is undoubtedly destructive to game and young poultry, all the birds of prey do good service to agriculture by destroying small rodents. Owls should on no account be molested, for they carry on the good work of diurnal birds of prey when the dusk falls, and they may be excused a little poaching. Goatsuckers and swifts, as well as woodpeckers, are purely insectivorous, and therefore undoubtedly beneficial. The cuckoo destroys many hairy caterpillars, which other birds do not touch.

Among the great host of perching birds, including most of the smaller species, the following may be classed as useful: jackdaw, jay (probably), starling (except to fruit-grower), yellow hammer and corn bunting, larks (although the skylark is taking to the bad habit of attacking the seedlings of wheat, etc.), wagtails and pipits, tree-creeper, nuthatch, tits (but may do some damage to buds and fruit, or destroy bees), thrushes

and blackbird (harmful to fruit-grower), chats, fieldfare, robin, wren, flycatchers, swallows and martins.

Birds Undoubtedly Harmful.—Pigeons and doves (excessively destructive to seeds and grain), and the following perching birds: hooded crow, bullfinch (destroys many buds), greenfinch, hawfinch, house sparrow (an unmitigated pest), blackcap and warblers (destructive to fruit).

Birds of Doubtful Character.—Two perching birds require mention here. Little is known about the **magpie**, although it is not sufficiently common to be of much importance. The abundant and prolific **rook** presents a difficult case. The most recent and extended observations are those by Mr. W. E. Collinge, who examined 830 birds, obtained from various counties at different times of the year. His results '. . . showed that 67·5 of their food consisted of grain, 3·5 per cent. of seeds, fruit, roots, and miscellaneous vegetable matter, 15 per cent. of wireworms and other insects, 10·5 per cent. of miscellaneous food (eggs, young game, field mice, etc.).' This seems a sufficiently black record, and is quite sufficient to justify considerable reduction in numbers (especially by destroying a certain percentage of the young—say, two squabs per nest), but the matter cannot be considered as finally settled. Such unexpected results often follow human interference with the balance of nature, that it is doubtful policy to wage a war of extermination, even against the notorious sparrow, for a species may be useful when present in moderate numbers but become a pest when it increases inordinately.

INSECTS

The natural orders of insects which possess the greatest interest for farmers are: Coleoptera, Hymenoptera, Lepidoptera, Homoptera, and Diptera. The termination of these words is derived from the Greek, *pteron*, a wing. The prefix refers to some peculiarity of the wings, these organs affording a convenient means of classification.

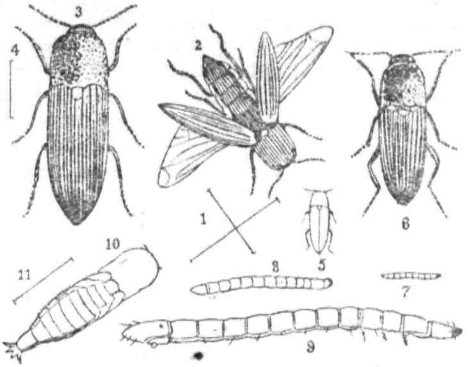


FIG. 243.—WIREWORMS AND CLICK BEETLES, *Elateridæ* (Coleoptera).

2, *Agriotes lineatus*, magnified ; 1, natural size.
3, *A. obscurus*, magnified ; 4, natural length.
5, *A. sputator*, natural size ; 6, magnified.
7, larva of *A. sputator* (?).
8, larva of *A. lineatus*, natural size ; 9, magnified.
10, pupa of wireworm, magnified ; 11, natural size.

FIG. 244.—COCKCHAFER, *Melolontha vulgaris* (Coleoptera), with (A) larva and (B) pupa.

The student is strongly recommended to examine, with the aid of a magnifying glass, any easily obtainable specimens of the orders which are briefly described below, and to verify as far as he can the characters which are here detailed. He should miss no opportunity of observing insects out of doors, but should look for them, in their various stages of existence, in the fields and hedgerows, in kitchen gardens and amongst farm crops, and by such means endeavour to learn their habits. It may be useful to read pages 634-7 before studying the characters of the natural orders.

Coleoptera (*i.e.*, sheath-winged) is the name of the order to which **beetles** belong. The front wings of beetles consist of a hard pair of wing covers (wing-sheaths or elytra), which overlap and protect the membranous folded hind wings. Beetles have biting jaws. All insects of this order pass through a complete series of changes—egg, larva, pupa, imago (p. 635). The larvæ are usually fleshy grubs, the mouth being furnished with jaws; they are mostly six-legged, and often have a fleshy foot (pro-leg) at each end of the tail. **Weevils** are a group of hard beetles provided with snouts; their larvæ are legless grubs.

Ladybirds are very useful beetles, for their larvæ feed upon aphides (p. 628). Ladybirds, therefore, should not be destroyed, but rather encouraged.

In the following table are named some of the commonest Coleoptera that infest cultivated crops. **Wireworms** (fig. 243) and **cockchafer grubs** (fig. 244) live in the soil for years, and attack the roots of grasses, cereals, and various other crops. The favourite food-crops of the other pests mentioned below are indicated in their popular names:—

Cockchafer (fig. 244)	*Melolontha vulgaris.*
Wireworms, larvæ of click beetles (fig. 243)	*Elateridæ.*
Turnip fly, or turnip flea-beetle (fig. 245)	*Phyllotreta nemorum.*
Mustard beetle	*Phædon betulæ.*
Turnip-blossom beetle	*Meligethes æneus.*
Bean-seed beetle	*Bruchus rufimanus.*
Turnip-gall weevil	*Ceutorhynchus sulcicollis.*

Apple-blossom weevil . . . *Anthonomus pomorum.*
Clover weevil . . . . . *Apion assimile.*
Nut weevil (fig. 246) . . . *Balaninus nucum.*
Pine beetle . . . . . *Hylurgus piniperda*

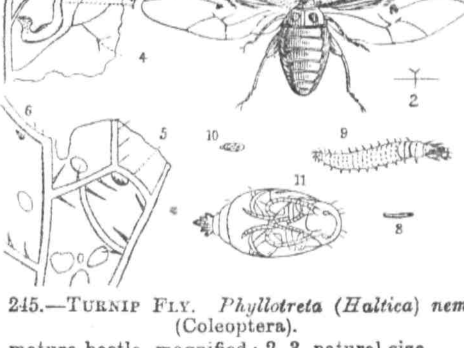


FIG. 245.—TURNIP FLY. *Phyllotreta (Haltica) nemorum* (Coleoptera).

1, mature beetle, magnified; 2, 3, natural size.
4, 5, eggs laid on under surface of rough leaf.
6, 7, burrows in leaf, made by larvæ or maggots.
8, larva, natural size; 9, magnified.
10, pupa, natural size; 11, magnified.

FIG. 246.—NUT WEEVIL, *Balaninus nucum* (Coleoptera).

Weevil magnified (natural length, $\frac{1}{4}$ to $\frac{1}{3}$ inch).
Pupa, natural size.
Maggot, natural size and magnified.
Damaged filbert.

HYMENOPTERA (*i.e.*, membrane-winged) are insects usually with four membranous wings, which possess but few veins, and are apparently naked, though sometimes bearing scattered bristles. The abdomen of the female is often furnished with a conspicuous ovipositor (or egg-laying apparatus), which is also used as a borer, or is developed as a sting. The mouth has biting jaws, and also a proboscis. The hymenoptera pass through a complete series of changes.

Two kinds of larvæ are met with. In some species, the larva is wormlike and legless (a 'maggot' or 'grub,'

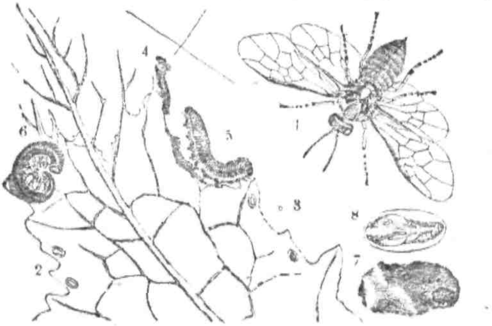


FIG. 247.—TURNIP SAWFLY, *Athalia spinarum* (Hymenoptera).
1, female sawfly, and lines showing natural size.
2, 3, eggs.
4, cast skin of a larva.
5, 6, larvæ.
7, oval silvery cocoon.
8, pupa.

such as the wasp-grub), and lives in nests stored with dead insects or pollen. In other species (the sawflies, figs. 247, 248, and 251) the larva has up to ten or eleven pairs of legs, and feeds on leaves, or stems, or in galls; it is these which are specially destructive to vegetation.

This is the order of the true stinging insects (bees, fig. 249—wasps, hornets), and of most of the parasitic insects (ichneumon flies, chalcis flies or brasslets, gall flies, fig. 250). **Ichneumon flies** are extremely beneficial forms, as the females lay their eggs in the eggs or larvæ of many noxious insects, within which the ichneumon larvæ live as parasites, ultimately destroying

their hosts. **Bees** are of great importance in the pollination of many flowers, which otherwise would not set seed, or do so to a small extent only. The **honey bee** (*Apis mellifica*) has been domesticated by mankind from time immemorial. Ants also belong to this order.

Of the following common examples of Hymenoptera, the **giant sirex** bores channels in the wood of pine trees,

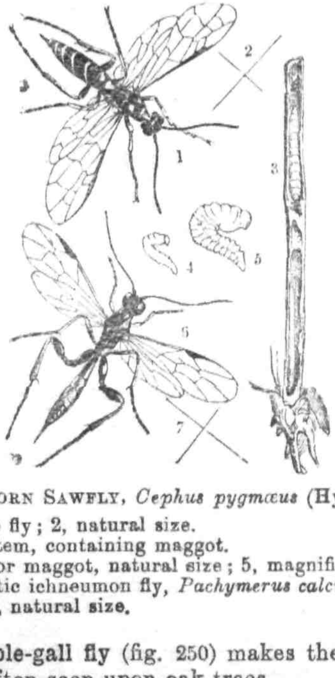


FIG. 248.—CORN SAWFLY, *Cephus pygmæus* (Hymenoptera).
1, female fly; 2, natural size.
3, corn-stem, containing maggot.
4, larva or maggot, natural size; 5, magnified.
6, parasitic ichneumon fly, *Pachymerus calcitrator*, magnified; 7, natural size.

and the **marble-gall fly** (fig. 250) makes the galls ('oak apples') so often seen upon oak trees.

Turnip sawfly (fig. 247) . .	*Athalia spinarum.*
Corn sawfly (fig. 248) . . .	*Cephus pygmæus.*
Gooseberry and currant sawfly .	*Nematus ribesiæ.*
Pear and cherry sawfly .	*Eriocampa limacina.*
Pine sawfly (fig. 251) . . .	*Lophyrus pini.*
Giant sirex, or wood wasp . .	*Sirex gigas.*
Marble-gall fly (fig. 250) . .	*Cynips kollari.*

LEPIDOPTERA (*i.e.*, scaly-winged) are the butterflies and moths, of which the latter are by far the more numerous. Lepidopterous insects possess four wings, which are usually covered with delicate scales of various colours.

FIG. 249.—HUMBLE BEES, *Bombus* spp. (Hymenoptera).
1, wood bee, *Bombus lucorum*.
2, 3, punctures in calyx of bean flower, through which nectar is withdrawn
4, earth bee, *Bombus terrestris*.

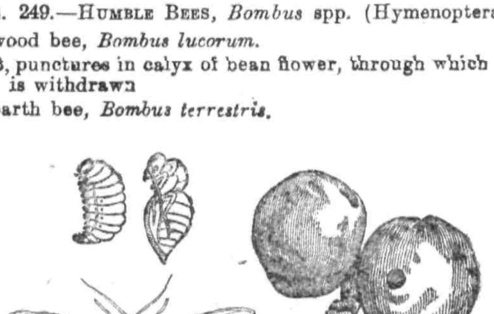


FIG. 250.—MARBLE-GALL FLY, *Cynips kollari* (Hymenoptera).
Larva, pupa, and mature insect, magnified.
Galls ('oak apples') of oak tree.

The organs of the mouth are adapted to sucking, the upper lip and jaws being small or rudimentary, and the lower jaws formed into a long tube (a proboscis) which, when not in use, is coiled up like a watch-spring, and concealed beneath the head.

These insects pass through a complete series of changes The larva is worm-like, with usually five to eight pairs of legs (occasionally none); it is furnished with biting jaws. Such a larva is termed a **caterpillar**. Most caterpillars are naked; a few are hairy. The intermediate inactive stage, or **pupa,** takes the form of a chrysalis.

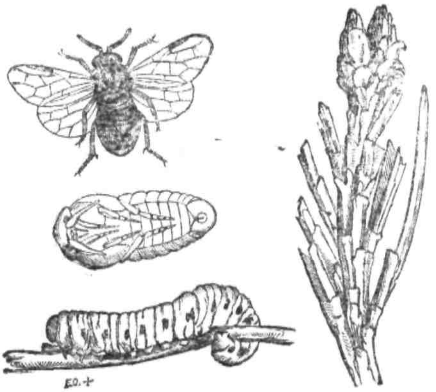


FIG. 251.—PINE SAWFLY, *Lophyrus pini* (Hymenoptera).
Larva, pupa, and mature insect, magnified.
Pine leaves injured by sawfly.

With scarcely an exception, all the insects of this order are injurious. Beautiful as are many of the Lepidoptera, their larval forms are very destructive to vegetation.

Butterflies have their antennæ, or 'horns,' terminating in knobs, like drumsticks. The antennæ of **moths** are not knobbed. Butterflies, when at rest, raise the wings so that they meet back to back, and show their dingy under sides, at the same time exposing their bodies.

Moths, when at rest, keep the wings spread out so as to cover their bodies. Butterflies usually fly by day; moths at twilight or at night.

Of the following familiar examples of Lepidoptera, the **surface caterpillars** (fig. 252)) attack the roots of turnips, cabbages, mangel, and other crops. The caterpillars of the **silver Y-moth** (fig. 253) feed on both **mangel**

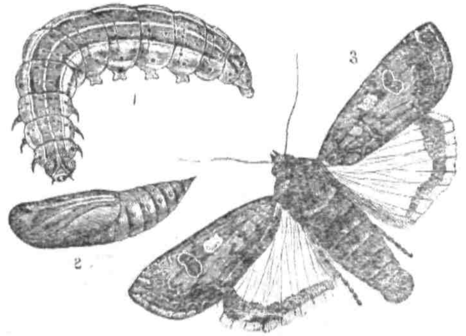


FIG. 252.—YELLOW UNDERWING MOTH, *Tryphæna pronuba* (Lepidoptera).

1, surface caterpillar. 2, chrysalis. 3, moth.

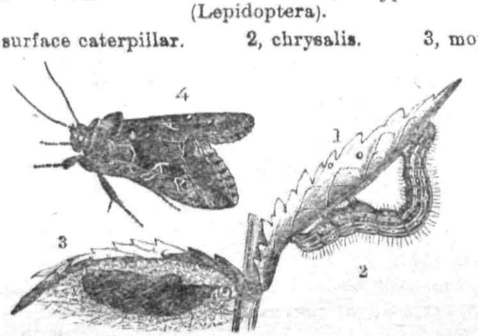


FIG. 253.—SILVER Y-MOTH, *Plusia gamma* (Lepidoptera).

1, eggs.
2, 'looper' caterpillar.
3, chrysalis inside cocoon.
4, moth; observe the y like mark on each wing, similar to the Greek letter gamma (γ).

and beet. The **magpie moth** attacks currant and gooseberry bushes, the **wood leopard moth** pear trees, and the **goat moth** oak and many other trees. The caterpillars of the **buff-tip moth** (fig. 254) injure the foliage of the lime, oak, and elm. The last five moths in the list are pests of orchard fruit trees.

White cabbage butterflies . .	*Pieris spp.*
Turnip diamond-back moth (fig. 255)	*Plutella cruciferarum.*
Yellow underwing moth (surface caterpillars, fig. 252) . .	*Tryphæna pronuba.*
Dart moth, or turnip moth (surface caterpillars) . . .	*Agrotis segetum.*
Silver Y-moth, or night-flutterer (fig. 253)	*Plusia gamma.*
Carrot-blossom moth . . .	*Depressaria daucella.*

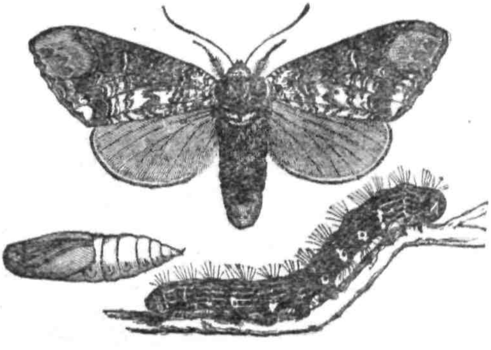


FIG. 254.—BUFF-TIP MOTH, *Pygæra bucephala* (Lepidoptera) with caterpillar and pupa.

Magpie moth	*Abraxas grossulariata.*
Wood leopard moth . . .	*Zeuzera æsculi.*
Goat moth	*Cossus ligniperda.*
Buff-tip moth (fig. 254) . .	*Pygæra bucephala.*
Winter moth	*Cheimatobia brumata.*
Codlin moth	*Carpocapsa pomonella.*
Lackey moth	*Clisiocampa neustria.*
Mottled umber moth . . .	*Hybernia defoliaria.*
Small ermine moth . . .	*Hyponomeuta padella.*

HOMOPTERA (*i.e.*, similar-winged) have wings of the same texture throughout, either wholly leathery or wholly membranous. The wings, when at rest, are held slantingly over the back, like a steep roof. Though four wings are usually present, there are only two in some species, and none in others. The mouth is fitted for suction, and is commonly called the 'beak;' it arises from the back part of the under side of the head. The antennæ are generally short.

The larva is much like the mature insect, and there is no quiescent pupa stage.

The Homoptera are terrestrial insects, and are all injurious to vegetation. With the HETEROPTERA (*i.e.*,

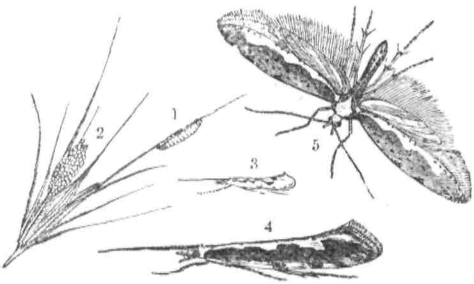


FIG. 255.—TURNIP DIAMOND-BACK MOTH, *Plutella cruciferarum* (Lepidoptera).
1, larva. 2, eggs.
3, moth, natural size; 4, 5, magnified.

dissimilar-winged)—an order including the **plant bugs** and certain water insects—they make up the division called HEMIPTERA (*i.e.*, half-winged).

The Homoptera are well illustrated by the **aphides** or **plant-lice** (also called 'smother-flies'), which include some of the most destructive insects known. In certain seasons the crops in bean fields (fig. 256) and hop plantations (fig. 257) are entirely ruined by the attacks of aphides, which are the most prolific of all insects. Foreign vineyards have been devastated year after year by *Phylloxera vastatrix*, which belongs to the same group as the aphides.

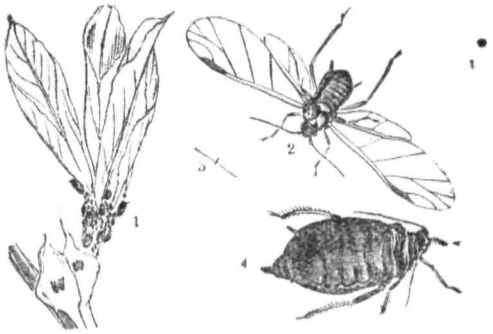


FIG. 256.—BEAN APHIS, *Aphis rumicis* or *Aphis fabæ* (Homoptera).

1, bean-shoot, infested with aphides.
2, winged male aphis, magnified; 3, natural size.
4, wingless female aphis, magnified.

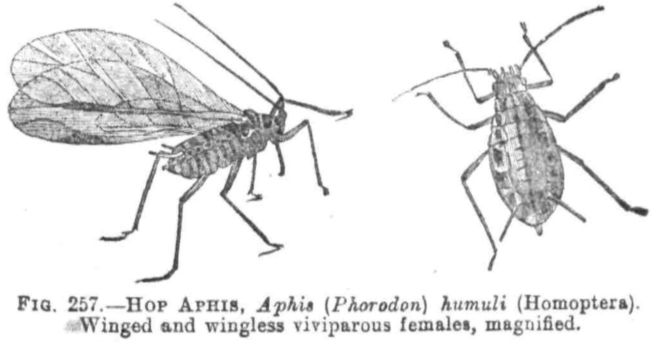


FIG. 257.—HOP APHIS, *Aphis* (*Phorodon*) *humuli* (Homoptera). Winged and wingless viviparous females, magnified.

The following are the names of common homopterous pests:—

Cabbage aphis, or green fly	*Aphis brassicæ.*
Turnip green fly	*Aphis rapæ.*
Bean aphis, black fly, or collier (fig. 256)	*Aphis rumicis.*
Potato frog fly	*Eupteryx solani.*
Hop aphis (fig. 257)	*Phorodon humuli.*

Hop cuckoo-fly	*Euacanthus interruptus.*
Corn aphis, or dolphin . .	*Siphonophora granaria.*
Plum aphis	*Aphis pruni.*
Apple sucker	*Psylla mali.*
Apple mussel-scale . . .	*Mytilaspis pomorum.*
American blight, or woolly aphis.	*Schizoneura lanigera.*
Woolly currant-scale . . .	*Pulvinaria ribesiæ.*
Larch aphis	*Chermes laricis.*

Lice (*not* bird-lice, for which *see* p. 634) are probably degenerate members of the Hemiptera.

Diptera (*i.e.*, two-winged) are characterized by possessing only one pair of wings, which have but few veins and are naked. In the place of the hind wings are a pair of structures, variously termed *halteres*, balancers, or poisers. The mouth is furnished with a proboscis, adapted for *piercing* or lapping. The female is stingless, and is but rarely furnished with a conspicuous ovipositor. The Diptera pass through a resting pupa stage. The larva is usually a worm-like legless maggot, with a soft retractile head, of no definite shape, though sometimes there is a hard head, furnished with jaws, as is the case with the grub of the daddy longlegs (fig. 258).

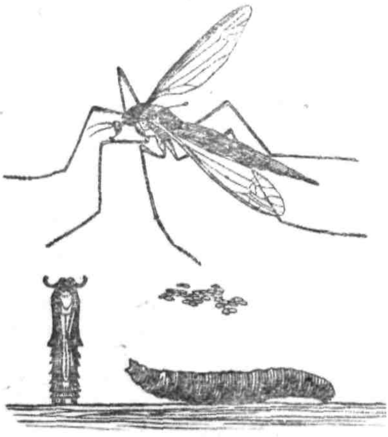


Fig. 258.—Daddy Longlegs, *Tipula oleracea* (Diptera), with eggs, grub (leather jacket), and pupa.

This is the order of the *true flies*, many so-called 'flies' (as turnip fly, sawfly, green fly) really belonging to other orders.

The **house fly** and the **blow fly** are familiar examples of the Diptera. The most destructive crop pest of the order is the **leather jacket,** which is the larva of the **daddy longlegs** or **crane-fly** (fig. 258). It lives in the soil, and like the wireworm (the larva of the click beetle —Coleoptera) it does great damage to the roots of plants.

The ox warble fly (fig. 259), horse bot-fly, gad flies, forest flies, sheep's nostril fly, the sheep 'tick' or ked, and mosquitoes are dipterous insects that cause much annoyance, and frequently serious injury, to animals. Some of the Diptera convey the germs of serious or fatal diseases into the blood of human beings or animals, which they bite. Some of the **mosquitoes,** for example, disseminate the germs of malaria and yellow fever. The **tsetse fly**

2 1 3

FIG. 259.—OX WARBLE FLY, *Hypoderma bovis* (Diptera).
1, mature fly.
2, maggot, which develops beneath the hides of cattle.
3, pupa.

(*Glossina morsitans*) infects horses with nagana or fly disease, and human beings fall victims to sleeping sickness when bitten by an allied species.

The fleas are a wingless group allied to this order. One of the **rat fleas** (*Ceratophyllus fasciatus*) appears to be responsible for the spread of Oriental plague.

Of the following common dipterous pests, the fever fly infests hops, and the Hessian fly, gout fly, and frit fly are cornfield pests.

Daddy longlegs, crane fly, or leather jacket (fig. 258) .	. *Tipula oleracea.*
Cabbage fly . . .	. *Anthomyia brassicæ.*
Celery and parsnip fly .	. *Tephritis onopordinis.*
Carrot fly, or 'Rust' .	. *Psila rosæ.*

Mangel fly	*Pegomyia betæ.*
Fever fly	*Dilophus vulgaris.*
Onion fly	*Anthomyia ceparum.*
Wheat midge, or red maggot .	*Cecidomyia tritici.*
Hessian fly	*Cecidomyia destructor.*
Wheat-bulb fly (fig. 260) . .	*Hylemyia coarctata.*
Gout fly, or ribbon-footed corn fly	*Chlorops tæniopus.*
Frit fly	*Oscinis frit.*
Ox warble-fly (fig. 259) . .	*Hypoderma bovis.*
Horse bot-fly	*Gastrophilus equi.*
Sheep's nostril fly . . .	*Œstrus ovis.*

FIG. 260.—WHEAT-BULB FLY, *Hylemyia coarctata* (Diptera).
1, mouth apparatus. 1a, maggot. 2, extremity of tail.
3, pupa 4, mature fly. 5, infested wheat plant.
1a, 3, and 4, natural size and magnified. 1 and 2, magnified.

There are, fortunately, some beneficial Diptera. The larvæ of **hover-flies** (*Syrphidæ*) destroy large numbers of aphides, while the larvæ of the **robber-flies** (*Tachinidæ*) are parasitic in caterpillars.

Two other orders of insects, Orthoptera and Neuroptera, may be briefly noticed, although they do not in this country furnish many injurious insects.

ORTHOPTERA (*i.e.*, straight-winged) have four wings, the anterior pair being leathery rather than (as in

Coleoptera) horny, and slightly overlapping; the hind legs are often formed for leaping. The jaws are adapted for biting. The larvæ live on the land, not in water (as is the case with Neuroptera), and there is no resting pupa stage.

Cockroaches, crickets, and **grasshoppers** belong to this order. In other countries **locusts**—very similar to grasshoppers—do immense mischief to vegetation. The curious exotic walking-stick and leaf insects are orthopterous. The **earwigs** which infest garden plants, and the **thrips**—a dark coloured fringe-winged little creature (fig. 261) often seen in the groove of the ripening wheat grain—may be placed here, though not actually included in the order Orthoptera.

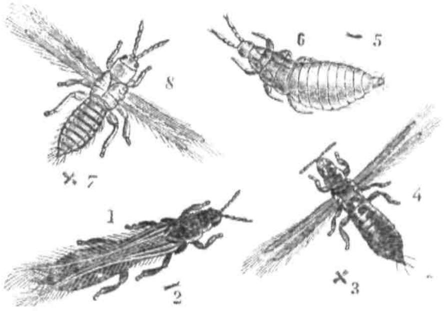


FIG. 261. THRIPS (near Orthoptera).

1, 4, corn thrips, *Thrips cerealium* or *Thrips physopus*, females magnified (1, walking; 4, flying); 2, 3, natural size.
6, 8, potato thrips, *Thrips minutissima,* magnified (6, the larva); 5, 7, natural size.

NEUROPTERA (*i.e.*, nerve-winged, or net-winged) have four wings, generally with numerous hollow veins, and either naked or hairy. The female seldom has a conspicuous ovipositor, and is never armed with a sting. The worm-like larvæ have six legs and are provided with jaws; they are mostly aquatic, and (with some exceptions) pass through a quiescent pupa stage.

Dragon flies, May flies (day flies, brown and green drakes), **stone-flies,** and **termites** (white 'ants') are examples of the Neuroptera, whilst the hairy-winged **caddis flies** are nearly related. **Bird-lice** (*Mallophaga*) probably belong to the same order.

Dragon-flies are decidedly beneficial, as they hawk for insects in the air, and many of those they destroy are noxious. The fragile **lace-wing flies** (*Hemerobiidæ*), with slender green bodies, gauzy wings, and golden eyes, lay stalked eggs, from which emerge rapacious larvæ, that are known as 'aphis lions,' because they destroy vast numbers of aphides.

Mouths of Insects.—Insects feed either by biting or sucking. The arrangement of the mouth of a biting insect

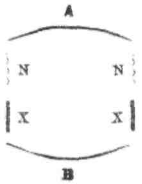


FIG. 262.—PLAN OF AN INSECT'S MOUTH.

A, Upper lip, or labrum. B, Lower lip, or labium.
N N, Mandibles. X X, First maxillæ.

(of a beetle, for example), as seen from the front, is shown in the diagram (fig. 262). There are three pairs of jaws (*a*) mandibles, (*b*) first maxillæ, (*c*) second maxillæ. The last are united into a lower lip (*labium*) between which and the upper lip (*labrum*), the mandibles and the first maxillæ work to and from the middle line, not up and down. In other words, instead of moving vertically, they move horizontally. The mandibles are biting jaws, and the first maxillæ are chewing jaws.

In a sucking insect, such as a butterfly, the first maxillæ are modified into two long slender half tubes, thus ( ). When these are in contact they form a canal, through which liquid can be sucked. This canal, being long, is coiled up when not in use. It is called the *proboscis*. In

some sucking insects (aphides, female mosquitoes) the mandibles and first maxillæ are in the form of piercing stylets.

There are gradations between the two types of mouths that have been described, but it is convenient to group insects as either Mandibulata (with gnawing mouths) or Haustellata (with sucking mouths):—

Mandibulata.	Haustellata.
Coleoptera.	Lepidoptera.
Hymenoptera.	Homoptera.
Orthoptera.	Heteroptera.
Neuroptera.	Diptera.

The **life-history** of many insects may be illustrated by that of a butterfly. The female butterfly lays **eggs**, from which, sooner or later, caterpillars (or **larvæ**) emerge. These feed actively and grow rapidly. When full-grown, they choose some place of security, or in many cases spin a cocoon (fig. 253), in which to change to the chrysalis (or **pupa**) state. There they moult their caterpillar skin, and lie with the undeveloped limbs pressed close to the body, gradually advancing to maturity under the protection of a strong outer film. In due time the outer coat cracks, and from within it comes the mature winged insect (or **imago**). The change from the grub-like larva to the beautiful imago has taken place during the resting stage, or quiescent period, represented by the pupa. After pairing, the female lays eggs and dies. Then the whole cycle is repeated:—

Imago
↗ ↖
Egg Pupa
↘ ↗
Larva

This is termed a **complete metamorphosis**, and it includes, as has been seen, a quiescent pupa stage. It takes place with insects of the following orders:—

Coleoptera.	Lepidoptera.
Hymenoptera.	Diptera.
Neuroptera.	

Certain groups of insects, on the other hand, have no intermediate quiescent stage after they leave the egg. The larva is then (fig. 261) much like the adult form, which is arrived at after several moultings. This is the case with—

Homoptera. Heteroptera. Orthoptera.

Structure of Insects.—The body of an insect is made up of rings, or **segments**, which can be better seen in the larva than in the perfect insect. In the mature form, from four to six segments go to make up the **head**, with its mouth-parts, the eyes, and the **antennæ** (horns, or feelers), though it is only by studying the development of insects that this fact can be proved. Next come three segments forming the **thorax**, each segment bearing a pair of **legs**—six legs in all. No perfect insect has more than six legs. **Wings**, when present, are borne by the second and third thoracic segments, never by the first or anterior thoracic segment. Succeeding the thorax is the **abdomen** (or 'tail'), made up of eight or more segments, and not furnished with limbs. In dragon-flies, the abdomen is often long and slender; in, for example, bees, it is much shorter. Some insects have a marked constriction, or 'waist,' at the junction of thorax and abdomen, as is the case in Hymenoptera. The head may fit loosely to the thorax, as in house flies; or be quite soldered to it, as in aphides. The hard parts of an insect's body are external, and form what is called the **exo-skeleton.** It is made up of a horny substance termed *chitin*.

An insect *breathes* by means of numerous **air-tubes** (*tracheæ*), which open at the surface of its body. By clogging up these pores with powders or other materials, an insect can be suffocated. Many methods of destroying insect pests are based upon this fact.

Identification of Larvæ.—When a mature insect is captured, it is not, as a rule, difficult to state the natural order to which it belongs. Beetles, moths, and dipterous insects, for example, are all sufficiently distinct. But, as many insects are specially destructive in the larval stage, it becomes of practical importance—especially

with a view of adopting remedial measures—to be able to determine of what order a larva is a member.

A **legless fleshy grub,** with a soft-pointed, retractile head (a 'maggot'), is *usually* one of the Diptera. But see Weevils (p. 620).

An **active six-legged grub,** with horny head and strong jaws, is usually that of a beetle (Coleoptera).

The so-called **caterpillars,** long, soft (sometimes hairy), with prominent head and jaws, and furnished with sixteen legs, belong to the Lepidoptera. When several of the intermediate pairs of legs are absent, a 'looper' caterpillar (as in the magpie, umber, and silver **Y**-moths—fig. 253) results.

Active, leaf-eating larvæ, with from 18 to 22 feet, usually belong to sawflies (Hymenoptera), and are termed **false caterpillars.**

The application of the foregoing facts will frequently render it easy to determine the natural order of any plant-eating larva belonging to an insect which undergoes complete metamorphosis.

Insect Attacks.—In order to cope successfully with the attacks of insects upon farm and garden crops it is useful, first of all, to appreciate certain entomological facts. It is, for example, a fact that certain insects are injurious at one stage of their life, and others at another. In most cases it is the **larval stage** that is specially destructive, as is the case with wireworms, leather jackets, and surface caterpillars. But this is no reason why the mature forms of click beetles, crane flies, and turnip or dart moths should not be constantly destroyed, for they are the parents of the depredators. Ants, wasps, and mosquitoes are examples of insects, the mischievous work of which is more especially associated with the **mature forms.** Cockchafers, aphides, and turnip-flies are actively aggressive in both the larval and the perfect condition.

There is no essential relationship between the duration of life of the larva and that of the imago. It does not follow, for example, that if the larval life is short the life of the imago will be long, or that if an insect

passes a long period in the larval stage it will enjoy but a brief perfect existence.

The length of life of a larva is determined by the facility with which it can obtain its food, and by the nutritive character of that food. The larval life of a bee occupies less than a week, for the grub, from the moment it is hatched, finds around it a profuse store of the richest food, consisting of honey and pollen. The blow fly, hatched out in meat, passes but eight or ten days as a larva. But the leaf-eating caterpillars of Lepidoptera have to work harder for their food, and this is of a less nutritious character, so that such larvæ often occupy six or eight weeks between egg and pupa. Wireworms and cockchafer grubs, which live in the soil and feed on roots, have a larval life extending over from one to five years.

Scarcely any part of a plant is free from insect attack. Such pests as weevils and bean beetles destroy seeds. The turnip fly pounces upon young cruciferous crops directly their cotyledons (p. 127) appear above ground. Leaves are specially susceptible—sawfly larvæ give leaves a scorched appearance, leaf-miners make tunnels in their tissues, gall insects cover them with swellings, the larvæ of leaf-roller moths coil them up to provide a shelter for their chrysalids, the caterpillars of cabbage butterflies riddle leaves with holes, and cockchafers devour leaves wholesale. Blossoms are destroyed by beetles and aphides. Stems, and even woody trunks, succumb to the attack of bark beetles, goat moth caterpillars, sirices, and other borers. The wireworm is the chief enemy of the roots of crops, but it has many helpers.

Some insects confine their attacks to **special groups of plants,** as the turnip fly to cruciferous crops. Others are **general feeders,** as wireworms and leather jackets. In dealing with the former class of pests, some knowledge of the relationships of plants, such as is set forth in chapter xii., is of considerable use.

If it be asked **why crops are so frequently ravaged by insects,** the answer is that, in growing vast numbers of the same kind of plant to the exclusion of other plants,

the cultivator has upset the natural balance of vegetation. If a cropped area were left to itself for a number of years, it would gradually develop a vegetation different from that which has been arbitrarily placed upon it. When extensive tracts of land, that would be otherwise naturally but diversely clothed, are covered by millions of wheat plants, or of turnip plants, or of bean plants, for example, the pests—be they insect or fungus—which prey upon such plants will naturally tend to increase in like proportion. In other words, side by side with the excessive, or exclusive, cultivation of one kind of plant, the pests—whether insects or fungi—which prey upon that plant may be expected to become more abundant, for they find their victims literally crowded together, and therefore extremely accessible. In wild nature a certain balance has become established between plants and their enemies, so that the former are kept in healthy check, but are not exterminated. Man's agricultural operations have artificially disturbed this balance, and he is often compelled artificially to redress the abnormal increase in insect pests which result from them. It is one object of the cultivator's skill, whilst he is extending the area under any given crop, to prevent or check a corresponding increase in the pests which infest that crop.

Natural Enemies of Insects.—Nature is at hand to help the cultivator. Some of the worst foes of crop-destroying insects are other insects, and these latter should be encouraged. Ladybirds, for example, devour all kinds of plant-lice (aphides); therefore, never kill a ladybird. Similarly for the other beneficial insects which have been mentioned under their respective orders. Insectivorous mammals, birds, etc., have been described in the earlier part of the chapter.

Not only should beneficial insects, birds, and mammals be preserved and encouraged, but they may sometimes be designedly enlisted in the service of man. It is often useful to introduce pigs, poultry, or ducks to an insect-infested crop, and there are cases on record where a pest which has been imported from a foreign country has been exterminated by bringing over and establishing

on the crop attacked the insect which was most instrumental in keeping the pest in check in the country of its origin. But these measures are often inadequate, and artificial interference is necessary.

There are two means of checking the ravages of insect pests—prevention and remedy. By **preventive methods** the appearance of the pest is forestalled, and either the surroundings are made too uninviting to induce it to stay, or the crop is maintained in so vigorous a condition that the insects are unable to effect any permanent injury upon it. Thus, a crop of young turnips just peeping through the ground may be lightly sprayed with paraffin, the odour of which will serve to keep the turnip fly at a distance until the plant is well established in the 'rough leaf,' for it is the smooth seed-leaves that the turnip fly is specially fond of. Again, bands smeared with grease and fastened round the trunks of orchard fruit trees will prevent the almost wingless female of the winter moth from crawling up the tree to lay her eggs upon the young buds. Rotation of crops (p. 308) affords another means of anticipating and obviating insect attack.

Remedial measures usually involve the application to the infested crop of substances which will either kill the insects (*insecticides*) or drive them away (*insectifuges*).

Now the primary consideration in treating injurious insects is that of **expense.** If it costs more to exterminate a pest than to suffer its ravages, it is obviously better to leave it alone. Especially is this true with regard to prevention. It is, of course, always a sound policy in treating an insect attack to deal with it so that as few individuals as possible shall survive to do future harm; and another preventive measure is always worth undertaking—namely, the destruction of weeds which are likely to encourage the pest. But expensive purely preventive measures are only advisable in two cases—either where the pest is an annual visitor, and may be counted on with tolerable certainty, or where the circumstances are such that we know from past experience that a pest will inevitably occur unless such measures are undertaken. If an orchard habitually suffers from winter moth

it may pay to spend money on banding the trees in autumn. If grass land is to be ploughed up it is certainly advisable to dress it with gas-lime, if this is readily obtainable, because an oat crop on newly-ploughed grass land is almost certain otherwise to be destroyed by wire-worm. But in a case of sporadic insect attack, which in all probability would not recur to a serious extent for many years, it would be foolish to incur much expense in attempting to prevent its appearance the following season.

Insecticides.—The same consideration affects our choice of insecticides. To be of practical use on the large scale they must be as cheap as possible, and this is why recourse is so often had to by-products of certain manufactures—such as gas lime and ammoniacal fluids—and to such comparatively plentiful substances as quick-lime, salt, soot, paraffin, and sulphur. Other substances, such as arsenic compounds, though somewhat expensive, are efficacious in such small quantities that they are capable of extensive use.

The selection of a suitable insecticide will, in the next place, depend on the nature and habits of the particular pest. When these are accurately known, it is generally found that the insect is most vulnerable at a particular stage in its life-history, and remedies can be used to the best advantage. Moreover, the danger is avoided of wasting money in futile operations, such as killing the insects after they have laid their eggs, or adopting measures—as in the case of the gentleman who used trap lamps for winter moth—calculated only to kill the males. It cannot be too strongly insisted on that the first thing to do in meeting with an insect attack is to find out exactly what the pest is and how it lives.

In dealing with the different orders of insects it was stated that some were **haustellate** (possessing sucking mouth parts), while others were **mandibulate** (with jaws adapted for biting). In the case of sucking insects, such as green fly, *only* those insecticides are of use which will destroy the pests by actual contact, but in the case of biting insects, which include the whole tribe

of caterpillars, it is often possible to proceed in a different way. By spraying the leaves on which they feed with an arsenical poison, at an early stage of the attack the insects may be *indirectly* destroyed while still very young, and before they have had time to do much harm. This method of treatment is of the highest value in the case of fruit-tree pests, though it is clearly inappropriate at or near the time when the fruit is ripe if, as is generally the case, the poison used is one which is injurious to man. We are here concerned only with the general principles of the use of insecticides, and any account of the treatment of special insect attacks would be out of place. It may be useful, however, briefly to review the various substances most commonly employed, and to indicate the nature of the cases in which their use is appropriate.

Gas-lime is chiefly used to cleanse land infested by root-feeding pests. It possesses at first poisonous and caustic properties, which pass off after exposure to the air for a time, and it is therefore necessary to leave it spread over the surface for some weeks before ploughing it in.

Soot, as well as possessing considerable manurial value, is a useful insectifuge, and renders leaves more or less unpalatable to biting insects. It is often distributed mixed with lime.

Paraffin oil, or petroleum, can also be used, much diluted, as an insectifuge, as in the case of turnip-fly, already alluded to, but it is also a useful direct insecticide. Emulsified with soft soap and water it is constantly employed against such pests as green fly, but much harm may be done by using oil of an inferior quality or of too great a strength.

Carbon bisulphide is a most useful and powerful insecticide, but it is so poisonous and inflammable as to be safe only in the hands of an expert. With the proper precautions it affords the best means of destroying the insects which infest granaries or other buildings, and it is also highly useful in combating root-feeding pests in the soil, and implements have been devised for infecting it among the roots of infested plants.

Various **arsenical** preparations (Paris green, lead arsenate, etc.) are used, as *indirect* insecticides, to poison the leaves on which insects are feeding, and thereby destroy the insects. Here the substance must be delivered as a fine spray, for the object is not to strike and destroy the insect directly, but to deposit a fine uniform layer of the poison on the leaves.

Tobacco, hellebore, and **pyrethrum** are ideal insecticides, in that they are highly destructive of insect life, but perfectly innocuous to plants and the higher animals, but unfortunately they are too costly for extensive use. They may be used as washes, but tobacco and pyrethrum are also effective as fumigants in enclosed spaces.

Hydrocyanic gas is a deadly poison, and one to be carefully avoided by any but an expert; but it is invaluable as a fumigant, and is especially used to clear young nursery stock from any pests they may harbour before planting them.

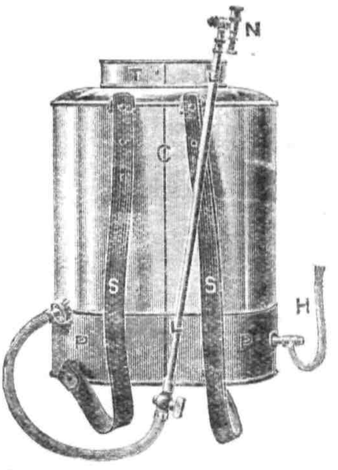


FIG. 262.—KNAPSACK SPRAYING MACHINE.

C, copper vessel containing solution to be sprayed.
T, top or lid, wherein is a strainer to prevent entrance of coarse particles.
P P, lower part of apparatus (made of steel) wherein is a pump actuated by the workman through the handle H.
L L, lance into which the solution passes by means of a flexible tube.
N, nozzle, from which the solution emerges in a fine spray.
S S, straps which pass over workman's shoulders.

Various **implements** have been placed on the market **for distributing insecticides** in the form of powders, washes, or sprays, and an illustration is here given of

an apparatus which is useful for operations on a small scale (fig. 262).

What is known as **good farming**—that is, thorough cultivation and liberal manuring—will prove highly serviceable in combating insect injury. The effective working of the land is most unfavourable to the persistence of insect life in the soil, as it turns out not only larvæ but pupæ as well, all of which are liable to be destroyed by the weather or to be eaten by birds. At the same time, everything that tends to promote plant growth will help to carry a crop speedily over those periods of its life when it is more than usually susceptible to insect attack.

ARACHNIDS

These Arthropods includes scorpions, spiders, and mites, of which the first-named require no mention here. The body is not divided into three distinct regions as in insects, for either the head and thorax are fused together (spiders), the abdomen remaining distinct, or all three regions form a continuous mass (mites), although the abdomen is usually marked off by a groove or suture. There are no antennæ, and four pairs of legs (not three, as in insects) are present. The life-history does not exhibit the complete metamorphosis characteristic of many insects.

Spiders are highly carnivorous forms, which destroy large numbers of noxious insects, and are therefore to be regarded as beneficial.

Some of the **mites** infest animals, while others attack plants. They are mostly very small or minute creatures, with which it is often difficult to deal.

Among **mites infesting animals** are included a number of species causing mange, scab, and itch. Some live on the surface of the skin, while others burrow in it and give rise to serious disturbance. Ordinary **sheep scab** is due to the presence of a particular species (*Psoroptes communis*), which burrows in the epidermis and leads to the formation of scabs (fig. 263). The so-called **head scab** is caused by another form (*Sarcoptes scabiei*).

Treatment consists in the use of various sheep-dips—*e.g.*, lime and sulphur; carbolic acid and soft soap; or tobacco and sulphur.

Poultry as well as mammals are liable to the attacks of mites related to the last-named form, two of these parasites (*Sarcoptes lævis* and *S. mutans*) being responsible, respectively, for feather-eating and 'scaly leg.'

The obnoxious **harvest bug** (*Leptus autumnalis*) is the six-legged larva of a mite (possibly *Trombidium holosericeum*).

The **red hen-mite** (*Dermanyssus avium*) attacks fowls and cage-birds at night, retiring to crevices in the poultry-house or bird-cage during the day, and greatly encouraged if these are allowed to get and remain dirty.

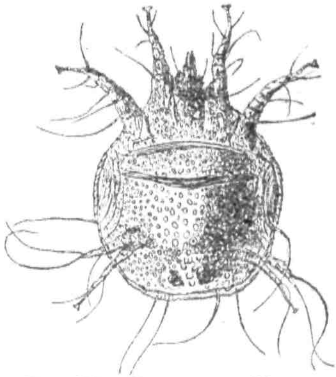


FIG. 263.—SHEEP-SCAB MITE (*Psoroptes communis*). Enlarged.

The large blood-sucking mites known as **ticks** torment various domesticated animals, and the true **sheep tick** (*Ixodes ricinus*) may be cited as an example. It is known that some of these parasites introduce disease-germs into their victims. This has been definitely proved for **Texas fever** in cattle, and appears to be also the case for **louping-ill** in sheep.

Mites which Infest Plants.—The group of **spinning mites** (*Tetranychinæ*), popularly known as **red spiders**, includes a number of species which are injurious to bush fruits and hops. The **gall-mites** (*Eriophyidæ* [*Phytoptidæ*]) attack fruit trees, the best known being the **black-currant gall-mite** (*Eriophyes* [*Phytoptus*] *ribis*), a very minute creature which lives in the leaf-buds of black currant (also white and red currants) and causes the disease known as 'big bud.' The related **pear-leaf blister mite**

(*Eriophyes* [*Phytoptus*] *pyri*) attacks the foliage leaves and young fruit of pear and apple. All the members of this family have elongated wrinkled bodies, and the two last pairs of legs are reduced to bristles.

The **bulb-mite** (*Rhizoglyphus echinopus*) attacks the swollen underground parts of tulip, lily, hyacinth, onion, and potato, as well as vine-roots. It is related to the **cheese-mites** (*Tyroglyphus siro* and *T. elatior*).

Plant-infesting mites are destroyed by powders, washes, and sprays, in the same way as injurious insects (pp. 641-4) and **sulphur** is reputed to be especially efficacious.

MYRIAPODS

This group of Arthropods includes Centipedes and Millipedes, in which the elongated segmented body is provided with numerous short legs. The head bears antennæ.

Centipedes are flattened from above downwards, each segment bears one pair of legs, a pair of poison claws is present in the neighbourhood of the mouth, and the antennæ are fairly long. These creatures are extremely active and purely carnivorous. As they feed on slugs, snails, insect larvæ, and worms, they may be regarded as purely beneficial.

Millipedes (fig. 264) have rounded bodies, each segment bears two pairs of feeble legs set on close together, there are no poison claws, and the antennæ are short (never more than seven joints). Millipedes, often known as 'false wireworms,' are sluggish vegetarians that do considerable damage to the underground parts of crop-plants. They are destroyed by lime, or trapped in scooped-out mangels.

ROUND WORMS (NEMATHELMIA)

The very numerous round worms and thread worms included in this group are mostly internal parasites, some attacking animals and some plants. The cylindrical

body is unsegmented—*i.e.*, not divided into rings or segments—tapering at the front or at both ends, and unprovided with limbs.

Round Worms Infesting Animals.—One of the most familiar species is the large **horse worm** (*Ascaris megalocephala*), often found in great numbers in the intestine of the horse and its allies. Far more injurious than this are the **palisade worms** or **strongyles**, of which the following are examples: **giant strongyle** (*Eustrongylus gigas*), in kidneys of horse, ox, and dog; **armed strongyle**

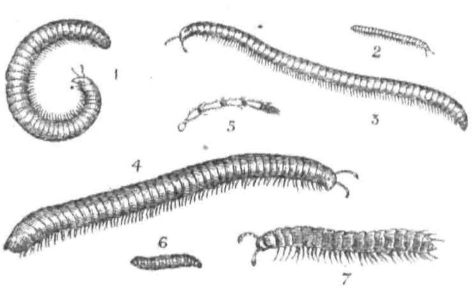


FIG. 264.—MILLIPEDES—'FALSE WIREWORMS' (Myriapods).

1, London snake-millipede, *Julus Londinensis*, of dark lead colour.

2, spotted snake-millipede, *Blanjulus guttulatus* (*Julus pulchellus*), of pale ochreous colour with crimson spots, natural size; 3, magnified.

4, earth snake-millipede, *Julus terrestris* (pitch-coloured), magnified.

5, its antenna, magnified.

6, flattened millipede, *Polydesmus complanatus*, colour lilac to whitish, natural size; 7, magnified.

(*Strongylus armatus*), which in the young state is swallowed by horses in drinking water, bores into the blood vessels and afterwards returns to the intestine, where it becomes adult; **sheep strongyle** (*S. contortus*), living in the fourth stomach of lambs, and causing serious disturbance; **lung worm** (*Filaria*), infesting the breathing passages of lambs and sheep; and the

gape worm (*Syngamus trachealis*), parasitic in the air-passages of fowls, and causing the disease known as 'gapes.'

One of the most dangerous pests is **trichina** (*Trichina spiralis*—fig. 265), a minute form, the adult sexual stage of which is found in the stomach of human beings, pigs, rats, and other flesh-eating animals. After pairing, the females produce innumerable living young, which bore into the blood-vessels, and are carried to the muscles, where they pass into a quiescent or encysted condition. The dangerous or fatal disease termed **trichinosis** is due to their presence, and is spread by the eating of uncooked or imperfectly cooked trichinous meat. Rats are largely responsible for the dissemination of this parasite.

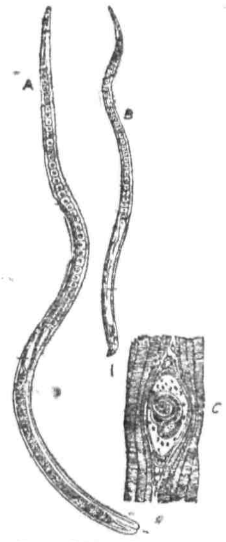


FIG. 265.—TRICHINA (*T. spiralis*). Enlarged. *a*, female. *b*, male. *c*, dormant stage encysted in muscle.

Round Worms Infesting Plants.—The minute forms known as **eelworms** (*Anguillulidæ*) cause several serious crop diseases. They include the following four species, among others. The **stem eelworm** (*Tylenchus devastatrix* — fig. 266) attacks the stems and leaves of rye, oats, buckwheat, clover, and potato, stunting the growth, and producing abnormal local thickening. 'Tulip root' of oats (fig. 267) may serve as an example.

The **wheat eelworm** (*Tylenchus scandens*) infests the developing grains of wheat, which become dark galls, variously known as ear cockles, peppercorns, and purples. The **beet eelworm** (*Heterodera Schachtii*) spends part of its life in the lateral roots of beet, which swell up into little galls; and this pest is responsible for what is known as 'beet sickness' of the soil. The closely related root-knot eelworm

(*H. radicicola*) lives in the roots of a large number of cultivated plants and weeds, and is especially harmful to clover, lucerne, cucumber, and tomato.

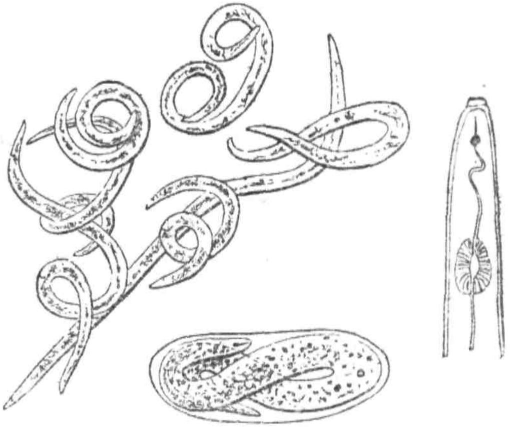


FIG. 266.—STEM EELWORM (*Tylenchus devastatrix*). Enlarged. Front end of a worm (further enlarged), to right, showing boring spine. Embryo coiled up in egg, below.

As in so many other cases, good farming and a rational system of rotation afford the best means of combating these pests. If seed wheat contains ear cockles, it should be pickled for twenty-four hours in weak sulphuric acid (one pint strong acid to thirty-three gallons of water).

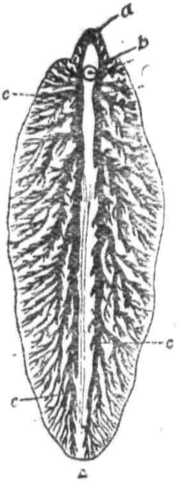
FIG. 267.—'TULIP ROOT' IN OATS.

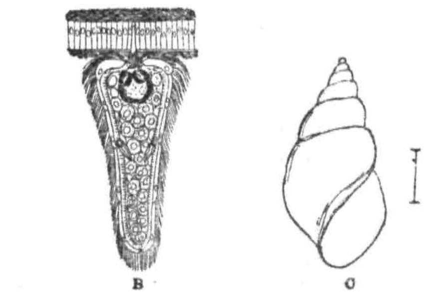
FLAT WORMS (PLATYHELMIA)

This group includes a large number of internal parasites that infest animals. They are unseg-

mented and their bodies are flattened. Two subdivisions are of economic importance—(1) Flukes (Trematoda) and (2) Tapeworms (Cestoda).

Flukes (Trematoda).—The best-known species is the **liver fluke** (*Fasciola hepatica*) that infests the liver and bile passages of the sheep, and causes 'liver rot' (fig. 268). The adult is of complicated structure, and is hermaphrodite—*i.e.*, possesses both male and female reproduc-





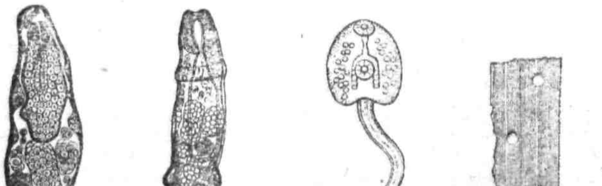


FIG. 268.—LIVER FLUKE (*Fasciola hepatica*).
a and *b*, suckers; *c c c*, branches of intestine.

A, Adult fluke.
B, ciliated embryo boring into snail.
C, water snail (*Limnæa truncatula*).
D, sporocyst.
E, redia.
F, cercaria.
G, cysts on grass.

A × 2, B, and D—F, highly magnified. Size of C indicated by line. G, slightly enlarged.

tive organs. The life-history may be summarized as follows:—

1. **Adult fluke** in liver of sheep (the *final host*) produces eggs that pass down bile-duct into intestine and to exterior in dung. Should they fall into water or on to a damp spot each hatches out into a—

2. **Ciliated embryo,** that swims actively about in search of the small water snail *Limnœa truncatula*, failing to find which in about eight hours it dies. If successful in its quest it bores into the lung of the snail (the *intermediate host*) and becomes—

3. A shapeless bag or **sporocyst,** within which is produced by internal budding—

4. The **redia,** that makes its way to the liver of the snail, and uses this as food. Several generations of daughter rediæ are produced by internal budding during the summer, but ultimately these are replaced by the next stage or—

5. **Cercaria,** resembling a tadpole in shape. This makes its way out of the snail, swims to a grass plant, loses its tail, and becomes encysted, its body being covered with a firm limy coat.

6. If a sheep swallows one of the cysts the limy covering is dissolved in its stomach and the **young fluke** passes up the bile-duct into the liver.

It is clear from what has been said that the disease cannot be directly communicated from one sheep to another, and that the most efficacious means of prevention are to be found in keeping sheep away from damp, badly-drained land, where the snail is likely to occur, while the source of the drinking water is a matter for special care.

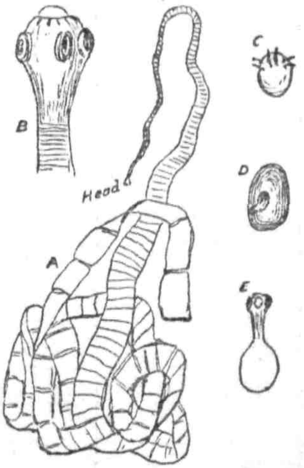


FIG. 269.—COMMON TAPEWORM (*Tœnia solium*).

A, adult worm.
B, head, enlarged.
C, six-hooked embryo, much enlarged.
D, encysted bladder-worm, enlarged.
E, bladder-worm with head protruded, enlarged.

Tapeworms (Cestoda).—We may take as an example the **common tapeworm** (*Tœnia solium* — fig. 269),

TABLE XLI.—TAPEWORMS.

NAME.	INTERMEDIATE HOST (sheltering bladder-worm).	FINAL HOST (sheltering adult worm).
Tænia mediocanellata (*saginata*). No hooks. Very numerous joints	*Cysticercus bovis.* Ox	Man (small intestine).
T. serrata. 38 to 48 hooks of two sizes. Numerous joints with prominent posterior angles	*C. pisiformis.* Rabbit (liver and mesentery)	Dog (small intestine).
T. marginata. Numerous joints, twice as long as broad	*C. tenuicollis.* Hoofed mammals (mesentery)	Dog (small intestine).
Bothriocephalus latus. Flat head, without hooks, but with 2 adhesive grooves. Very numerous broad joints	Embryo ciliated: passes into first intermediate host (probably an invertebrate) and then into pike or burbot (second intermediate host)	Man (small intestine) Rarely cat or dog.
Tænia cœnurus. 24 to 32 small hooks. Numerous joints	*Cœnurus cerebralis.* Large bladder, producing several tapeworm heads. Sheep (brain, causing 'staggers,' or 'gid')	Sheep - dog (small intestine).
T. echinococcus. Minute. Numerous very small hooks. Only 3 or 4 joints	*Echinococcus veterinorum.* Very large compound bladder, producing many tapeworm heads. Man and domestic hoofed mammals (liver and other organs)	Dog (small intestine).

which in its adult condition lives in the small intestine of human beings, and when immature in the muscles of the pig, where it causes the condition known as 'measly.' The adult consists of a minute head (*scolex*), provided with hooks and suckers for clinging to the lining of the intestine, and a long series of flattened joints ('proglottides'), each of which contains a complete set of male and female reproductive organs. These joints are not comparable to the rings or segments of an earthworm, centipede, or insect, but may be regarded as a series of buds, the youngest of which are next the head. There are no digestive organs, for the food consists of the digested substances present in the intestine of the host, and which are absorbed by the general surface of the body.

The ripe proglottides (furthest from the head) contain a large number of embryos which have developed within the firm coverings of the eggs. They pass out to the exterior in the excrement. The stages in the life-history are as follows:—

1. If a pig (the *intermediate host*) swallows a ripe tapeworm joint, the embryo, by the action of the gastric juice is liberated from its investments, and by means of the six hooks it possesses bores into the blood-vessels of the stomach, and is carried to one of the muscles, where it—

2. Passes into the encysted or **bladder-worm stage**, known as *Cysticercus cellulosæ* in this particular case. It is a hollow sphere an ingrowth into which becomes a tapeworm head.

3. Development can proceed no further unless the bladder-worm or 'measle' is swallowed by a human being, when the tapeworm head is protruded, attaches itself to the lining of the small intestine and buds off a series of joints, thus becoming an adult.

Details regarding a few other tapeworms are given in Table XLI., p. 652.

ANIMALCULES (PROTOZOA)

This subkingdom includes a vast number of minute or microscopic animals, varying greatly in structure, and

divided into numerous groups. The body of a Protozoon consists of a single cell, and is therefore said to be *unicellular*.

Protozoa swarm in the soil, and some of them devour the beneficial bacteria concerned with nitrification. Sterilization of soil or its treatment with various chemical substances destroys these Protozoa, as well as the bacteria. The spores of the latter, however, survive and give rise to fresh crops of bacteria, which, being freed from their enemies, are able to multiply to an abnormal extent, bringing about unusual fertility.

FIG. 270.—TRYPANOSOMES. Highly magnified. A, single individual B, individual dividing into two.

Protozoa of Disease.—Of late years it has been discovered that a number of diseases are due to blood infesting Protozoa, many of which pass through a characteristic **trypanosome** stage (fig. 270). A dipterous insect or a tick (*see* pp. 631, 645) is the means of conveying the disease. A few such diseases are summarized in the following table:—

TABLE XLII.—TRYPANOSOME DISEASES.

Name of parasite and disease.	Where occurring.	Animal affected.	Infecting Agent.
Trypanosoma brucei. Nagana or fly disease	Tropical Africa	Horse and ox ...	Tsetse fly (*Glossina morsitans*).
T. gambiense. Sleeping Sickness	Tropical Africa	Man	Tsetse fly (*G. palpalis*).
T. evansii. Surra	India	Ruminants ...	Probably a Gad-fly.

TABLE XLII.—TRYPANOSOME DISEASES—*continued.*

Name of parasite and disease.	Where occurring.	Animal affected.	Infecting Agent.
T. equiperdum. Dourine	Algeria and Punjab	Horse and dog	—
T. equinum. Mal de Caderas	South America	Horse	—
T. theileri. Bile-sickness	Transvaal ...	Cattle	—
Piroplasma. Texas fever	North America	Cattle	A Tick (*Boöphilus annulatus*).
Piroplasma. Louping-ill	Great Britain ...	Sheep	Sheep Tick (*Ixodes ricinus*).

Malarial diseases are due to other Protozoan blood parasites (species of *Hæmamœba*) introduced by the bites of dapple-winged mosquitoes (species of *Anopheles*).

Lincolnshire Red Shorthorn.—This is a special strain of Shorthorns, distinguished by a deep cherry red colour, supposed to have been originated by Thomas Turnell, of Wragby, towards the close of the 18th century, and much less in-bred than the ordinary type. A distinct Association and Herd-book date from 1895, and the strain differs so little from the parent stock that a red bull registered in Coates's Herd-book is considered suitable for use, so that its progeny could be entered in the Lincoln Red Herd-book.

The breed is officially described as possessing length of frame, good constitution, great hardiness, marked powers of milk-yielding, and heavy carcase. It has taken a leading position of late years in Milk and Butter Competitions at important Shows, and is increasing in popularity, not only at home but also abroad, especially in hot countries, to which its colour appears to be well adapted.

British-Holstein.—This is a naturalized Dutch breed, taking origin from the black-and-white Friesian cattle (with some infusion from other Netherland races) formerly imported in large numbers into the eastern part of Great Britain from Aberdeenshire southwards. A special Breed Society was formed in 1909. The milking qualities of the breed are highly developed, but the quality of the milk will bear improvement, although the unusually minute fat-globules render it particularly suitable for cheese-making.

The following points are to be looked for:—Frame large, and of dairy type, but less specialized than in Channel Islands breeds. Colours: black-and-white (in sharply defined patches) predominating and most favoured; dun, dun-and-white, and black also recognized. Head unusually long, fine. Well-bent horns, forwardly inclined, with no upward turn. Neck slender and rather long. Coupling long; belly low and unusually capacious. For a dairy breed the chest is deep through heart, with relatively thick withers and shoulders.

STEAM ENGINE AND TRACTOR CULTIVATION.

Nearly all operations in connection with the cultivation of the land may with advantage be effected either by steam cultivation or by motor tractor, though the lighter operations may be done by a horse.

The main advantage in either system, consists in the fact that a greater amount of work may be done in a given time than with horses, thus enabling the farmer to avail himself to a greater extent ot favourable conditions, to get not only a maximum amount of work done, but to get it better done, the condition of the soil being more friable.

Several systems of steam cultivation have been brought out, but the most successful has been the double engine system, the plough being hauled across the field and back by an engine with winding-drum at either end of the field.

Such a plant obviously represents the expenditure of considerable capital. This may be fully justified on a large area of tillage, but would be excessive for a small holding. In the latter case the work may be done at an agreed price per acre, by owners of tackle, who make a business of doing the work.

Direct Traction.—Several attempts in past years were made to drag the plough direct by means of the ordinary steam traction engine. These were abandoned owing to the excessive weight on the engine wheels unduly compressing the land, as well as on account of the power taken to propel a heavy engine over the soft ground.

The introduction of the motor tractor with its reduced weight has brought "direct traction" again to the front and the experience gained during the last few years has established its efficiency under suitable conditions.

There are numerous forms of tractors, the relative merits of which cannot be discussed here. It may, however, be pointed out that one fruitful source of failure arises from over estimating the work which may be done by a tractor of a given power. The slight additional cost—of say an extra 5 B.H.P.—may make the

whole difference between success and failure, and prove a very prudent expenditure of capital.

Generally the power should be such as to easily pull a three-furrow plough, at a suitable speed and depth, in the land to be ploughed.

If sufficient power for ploughing is provided it will be found that other operations will be amply provided for.

From the farmer's point of view a good general purpose tractor is what he requires.

The conditions of traction for ploughing, and on a road, are so very different, that a perfect combination is not so easy to produce as might appear.

Due consideration must therefore be given to the purposes for which the tractor is to be used.

It should also be capable of conveniently driving a thrashing machine, circular saw, or other estate machinery.

THE BREAKING UP OF PERMANENT GRASS.

The process of converting permanent pasture into arable land is new to the experience of many present-day agriculturists, and it presents many problems which call for somewhat special knowledge to deal with successfully. Recent experience has shown that old grass land broken up in a particular manner, and at a particular time has yielded excellent crops — while similar land treated differently has given very disappointing results. Experience also shows that the results vary according to the character of the soil, and that to ensure success the method of cultivation must be adapted to the type of land with which the farmer has to deal.

Grass land varies much in quality and in its capacity for production in the way of meat or milk. In general, land under arable cultivation is capable of a greater total production of food than land under grass, but some pastures are more likely to yield satisfactory results when ploughed than others. The suitability of any particular pasture field for arable

cultivation is determined by such a consideration as whether the land is of a character generally as to make it reasonably probable that it will, with proper cultivation, yield remunerative crops. Wet, undrained land, very heavy adhesive clays, excessively dry sandy soils and land at a high elevation are not in general likely to prove profitable under arable cultivation. On the other hand, a very large area of land in this country that is now in pasture could with great advantage, both to the farmer and to the nation, be converted into arable land. The better pastures contain stores of fertility, which, when once opened up by proper cultivation, become available for successive crops, while much land that now only carries an inferior sward could be so improved by arable cultivation that its yield could be very largely increased. Nevertheless, in view of the variable character of the land under grass in this country, the selection of pasture land for conversion into arable, calls for the exercise of judgment.

BREAKING UP.

Heavy Soils.—On both heavy loams and clays there is much grass land that has been ploughed up within the last two seasons. It happens that in certain districts of the country, notably in the Midlands and South of England, a very large proportion of the pasture on these two types of soil is of an inferior character, and a considerable area is derelict. It is generally necessary that old pastures on the heavier classes of land should have a summer fallow. If possible, the land should be broken up in May, and at the latest as soon as the hay harvest is over. For this purpose, and especially on large areas, steam tackle has great advantages. The turf in the case of inferior grass land is often largely composed of weeds, and it is necessary for proper cultivation and cleaning that the turf should be killed on the surface and not buried in the soil. On good grass land, on the other hand, where the turf is of good quality, and the soil is deep, the turf should be buried to rot in the ground. It is an advantage, where the

land is broken up early in the season, that is in May or the beginning of June, to leave the land in a rough state. The sun and the rain will so act upon the clouds that they can later be easily broken up, and will thus do for the farmer largely what he must himself do by means of the cultivator and the harrow, with little aid from sun and rain, when the grass is not broken up till August or later. With land that is not broken up before August, it is particularly desirable that it should not be ploughed deeply in the first instance. A shallow and somewhat flat furrow is in itself more effective in killing the turf, and it also makes it easier for subsequent cross ploughing. If the object in view is to secure a sufficiently fine tilth for the sowing of wheat in the autumn the early breaking up of the land with steam tackle so that it may receive the full benefit of the sun during a summer fallow, is, on the types of soil under consideration, and especially with an inferior turf, the method best calculated to secure this, especially in the drier parts of the country.

The treatment of a summer fallow after the first breaking up will depend to some extent on the state of the land and on the weather. In some recent cases, one ploughing in July followed by thorough disc-harrowing several times and then cross-ploughing with subsequent disc-harrowing as before has been found sufficient to break up the turf to such an extent that a satisfactory seed-bed for wheat was obtained by the end of September. The aim being to kill the sod, and break up the clods, the condition of the fallow will largely determine the course to be followed in any particular case with a view to securing this end. The use of certain modern implements, particularly the disc-harrow, has in many cases materially simplified the process of making a seed-bed from old turf, and rendered less necessary the repeated ploughing and dragging which were at one time considered essential.

When the pasture has not been broken up until after harvest, it is only occasionally that it can be brought into a fit state to be put under a winter crop, and, except under special circumstances, it will be better in any

case not to sow till the spring, after the land has had full benefit of the winter frost.

If a poor pasture or heavy land cannot be broken up before the autumn or winter, the method of ploughing should then be modified. Instead of a shallow, flat furrow, a deep and inverted furrow should be aimed at.

Light and Medium Soils.—The lighter classes of land are more easily brought under cultivation than the heavy loams and clays dealt with above, but even on these there is frequently found a thick matted turf, which if not thoroughly broken up and rotted may interfere materially with the crop. Pastures on light land are not generally broken up to be sown with a winter crop like wheat or beans, but for some spring crop. While fallowing may not be necessary on these soils, they should as a rule be ploughed early in order that the turf may have time to rot before the crop is sown, especially when the sod is thick and matted. An effort should be made to plough between Christmas and the latter end of January, and generally a flat furrow will probably be best. Where the turf is of better quality, or is thin, the ploughing may be deferred until later, but the late ploughing of grass land is not as a rule to be recommended, although recent experience would seem to show that in some southern districts corn sown on land ploughed as late as March is likely to suffer less wireworm attacks than that on land ploughed early.

A flat furrow is usually to be recommended, but where the corn, which will generally be oats, is to be sown broadcast, as is the case in hill districts, the furrow may have more of a "crest" on it than when the drill is to be used. In ploughing grass land in spring, and especially if late, a skim-coulter should always be used.

Where the land is of good quality, and the pasture rich, it will be more suitable for potatoes than for corn, as the latter would probably lodge and lose much of its value. If the turf is very thick, an effort should be made to break it up so as to avoid the difficulty that would otherwise be experienced in moulding up the potatoes. To do this effectually, the land should be

ploughed up with a shallow furrow early in winter. Later on the sod should be broken up with a cultivator or drag harrow, and the land ploughed deep, so as to cover the broken sod. If a disc harrow is available this should be used for breaking up the sod. Much labour and time may be saved in this way. In any case it is not necessary for potatoes that the turf should be broken up very fine, and experience shows that the crop grows well in land which has in it a considerable quantity of sod, provided the latter is sufficiently broken up so as not to interfere materially with the after cultivation of the crop.

Good pasture on deep rich loam or silt may be prepared for potatoes by ploughing to a depth of 10 to 12 inches, and having the sod buried at the bottom. For this two ploughs are employed. The first takes off the surface layer of about 2 or 3 inches, and the second, which follows the first in the same furrow, ploughs to a further depth of 6 to 9 inches, and turns the furrow over on the top of the sod. In this manner a deep bed of pure soil is obtained for the potatoes, while the sod rots underneath and is brought to a condition by the following season in which it will readily mix with the soil and add to its richness.

Procedure after Breaking Up.—In breaking up old grass land on nearly all classes of soil, somewhat special methods of treatment have to be adopted in order to secure the necessary tilth, and especially the breaking up and rotting of the turf. It is, however, on the clays and heavy loams that the process is most difficult and lengthy, and where it calls for most intelligence and skill. Assuming that a pasture on land of this character is broken up by steam tackle in early summer in the manner already described, and that by subsequent ploughing or disc-harrowing, or both, the sods and clods have been thoroughly broken up, a final ploughing and harrowing is all that is needed before the seed is sown. The treatment of the land after the crop is sown does not differ in any material sense from that of ordiary arable land.

In the case of light land which has been broken up

from grass, and which is sown with spring corn, it is specially important that the methods of cultivation adopted should be such as to ensure that the land is in the end thoroughly consolidated. It is for this reason that a flat furrow is so much to be desired. As a further means of attaining this end thorough rolling or pressing is to be insisted upon, especially in a dry district and in cases where the land has been ploughed late, where the ploughing has been badly done, or where the turf is very thick. The experience of the past two seasons has shown that the proper consolidation of the land under these circumstances is often a determining factor in the successful growing of spring corn after old grass. In addition to its other effects, rolling is a useful means, as has long been recognised, of checking the ravages of wire-worms and leather jackets, which are often a source of trouble on newly broken up grass land.

To obtain proper tilth, where, owing to late ploughing or some other cause, the surface is not in a condition to make a satisfactory seed-bed, disc-harrowing is of great value, and many of those who have recently broken up old pasture attribute their success to this operation. The disc drill would appear also to have substantial advantage over the ordinary drill especially on land where there is a tough sod.

Cropping.—On heavy land that has been summer fallowed winter wheat is the crop that should generally be sown. Beans may be sown in particular cases. Where land of this type has been broken up too late to allow of an autumn sown crop to be taken, spring-wheat or oats may be sown. It should be stated, however, that spring oats are more likely to succeed to the North and West than in the South of England. Excellent crops of mangels have been grown in some cases on land of this kind. Peas have also been grown successfully, and may be recommended in many cases for late sowing, though they are not equal to beans generally, if the latter can be sown before the end of February.

The crops that may be taken after old grass on light land and loams are more varied. On the best soils, as

has been indicated, potatoes may be grown very successfully, and are in many cases the best crop to take. Spring wheat will do well as also will barley and peas in cases where the land is good and where proper tilth has been secured. Oats, however, are generally the best crop to sow on this type of land as they also are on heavier lands which have not been ploughed early, especially in the North and West. On very poor light soils, rye will often give good results if sown early.

Manuring.—Where good grass land has been broken up, good and even remarkable crops may be grown without any manure being applied. Old pasture broken up, however, is often very poor, especially in phosphates, and under these conditions a dressing of from 2 to 4 cwts. of superphosphate or basic slag is necessary in order to secure a satisfactory corn crop. The addition of half to one cwt. of sulphate of ammonia is advisable in cases where the crop appears backward in the spring, or where it is seen to suffer from insect attacks. On old grass land with a thick matted turf, lime often gives excellent results, both when applied on a summer fallow and on land broken up in the winter or early spring. Where there is much old tough sod to be broken up, whether on heavy or on light land, lime is a most useful agent to employ, while on stiff sour clays, and heavy loams, it has a special value for its "sweetening" effects apart from the aid which it gives in disintegrating the turf. Quantities varying from one to three tons per acre (according to the character of the soil) have recently been applied to newly broken up land with much success.

INDEX

ABDOMEN, 408
Aberdeen-Angus cattle, **500**
Abomasum, 427, 428
Abraxas grossulariata (*see* Magpie moth)
Absorption, **447**
Acetabulum, 412
Acetic acid, **306**
Acer campestre, L. (*see* Maple)
— *pseudoplatanus*, L. (*see* Sycamore)
Achene, 175
Achillea millefolium, L. (*see* Yarrow)
Acidimeter, 573
Acid phosphatic manures, **117**
Acids, 18
Acorn, 135
Acquired characters, **474**
'Action' in horses, **483**, **485**
Adonis autumnalis, L. (*see* Pheasant's eye)
Adventitious roots, **145**, **150**
Æcidiospore, 388
Æcidium, 388
Aerial stems, **149**
Aërobic bacteria, **39**
Æsculus Hippocastanum, L. (*see* Horse-chestnut)
Æthusa Cynapium, L. (*see* Fool's parsley)
Afterbirth, 451
Aftermath, 230
After-pruning, **364**
After-sickness of potatoes, **400**
Agaricus campestris (*see* Mushroom)
Agrimony (*Agrimonia Eupatoria*, L.), 203
Agrotis segetum (*see* Turnip moth)
Agrostis alba, L. (*see* Bent grass, marsh); *A. alba*, var. *stolonifera* (*see* Bent grass, creeping); *A. vulgaris*, L. (*see* Bent grass, common)
Aira cæspitosa, L. (*see* Hair grass, tufted); *A. flexuosa*, L. (*see* Hair grass, wavy)
Air, 7; — of the soil, 21.
Air-sacs, 443
Air-tubes, 636
Ajuga reptans, L. (*see* Bugle)
Ala, 168
Albumin, 431
Albuminoid ratio, 463
Albuminoids (*see* Proteins)
Albuminous seeds, **134**, **135**
Alchemilla vulgaris, L. (*see* Lady's mantle)
Alimentary canal, 425
Alkalies, 12
Allium ascalonicum, L. (*see* Shallot); *A. Cepa*, L. (*see* Onion); *A. Porrum*, L. (*see* Leek); *A. vineale*, L. (*see* Onion, wild)
Alluvial soil, 6
Alopecurus agrestis, L. (*see* Foxtail, slender); *A. geniculatus*, L. (*see* Foxtail, floating); *A. pratensis*, L. (*see* Foxtail, meadow)
Alsike clover (*Trifolium hybridum*, L.), 195
Alternate, 156
Alumina, 11
Aluminium, 12

Alveoli (of udder), 549
American blight, 630
— gooseberry mildew (*Sphaerotheca mors-uvae*, Berk. et Curt.), 395
Amides, 432
Ammonia, 7, 12, 30, 34, 36, 37, 38
Ampelopsis spp. (*see* Virginia creeper)
Amphibians, 609
Amylolytic, 138, 433
Amylopsin, 434
Anabolism, 141
Anaërobic bacteria, 40
Anagallis arvensis, L. (*see* Pimpernel, scarlet)
Analyses of foods, Chap. xxi.
— of manures, 107-8, 114, 116, 118, 120
— of soils, 16-18, 20-22
Anas boschas (*see* Mallard)
Anatomy, 407
Anbury (*see* Club-root)
Anemone, wood (*Anemone nemorosa*, L.), 264
Anemophilous, 170
Animalcules, 653
Ankle, 416
Annatto, 573
Annelids, 610
Annuals, 159
Anser ferus (*see* Gray-lag Goose)
Antenna, 636
Anterior, 408
Anthemis Cotula, L. (*see* Stinking chamomile)
Antheridium, 401
Anther, 163
Anthonomus pomorum (*see* Apple-blossom weevil)
Anthoxanthum odoratum, L. (*see* Vernal grass, sweet-scented); *A. Puelii* (*see* Vernal grass, Puel's)
Anthomyia brassicæ (*see* Cabbage fly); *A. ceparum* (*see* Onion fly)

Anthyllis vulneraria, L. (*see* Kidney vetch)
Antirrhinum majus, L. (*see* Snapdragon)
Antiseptic, 392
Ants, 623
Anus, 427
Aorta, 437
Apatite, 115
Aphides, 628
Aphis brassicæ (*see* Cabbage aphis); *A. pruni* (*see* Plum aphis); *A. rapæ* (*see* Turnip Green fly); *A. rumicis* (*see* Bean aphis)
— lions, 634
Apium graveolens, L. (*see* Celery)
Apion assimile (*see* Clover weevil)
Apis mellifica (*see* Honey-bee)
Appendicular skeleton, 408
Apocarpous, 167
Apple (*Pyrus malus*, L.), 135, 161, 361, 366, 373, 375, 376
— blossom weevil (*Anthonomus pomorum*), 621
— grass orchard, 361
— mussel scale (*Mytilaspis pomorum*), 630
— sucker (*Psylla mali*), 630
Application of manures, 122
Apricot, 375
Aqueous rocks, 7
Aquilegia vulgaris, L. (*see* Columbine)
Arable land, 307
Arachnids, 644
Arch (of vertebra), 408
Arctium Lappa (*see* Burdock)
Arrhenantherum avenaceum, Beauv. (*see* Oat-grass, tall)
Arsenical preparations, 643
Arterial blood, 437, 440
Artery, 437
Arthropods, 609
Artichoke (*Cynara Scolymus*, L.), 212

Artificial manures, 111; **distributors of, 69**
— pollination, 173
— selection, 472
Artiodactyles, 423
Arvicolidæ, 613
Ascopore, 394, 396
Ascus, 394, 396
Ash (*Fraxinus excelsior*, L.), 161
— (in analyses), Chap. xxi.
Asparagin, 431
Asparagus (*Asparagus officinalis*, L.), 161, 162, 221
Astragalus, 417
Atavism, 473
Athalia spinarum (*see* Turnip sawfly)
Atlas vertebra, 410
Atmosphere, 1, 7
Atropa belladonna, L. (*see* Nightshade, deadly)
Aubrietia, 179
Aubergine (*see* Egg-plant)
Auricle, 436
Autumn cultivation, 99
Available plant food, 17
Avena elatior, L. (*see* Oat-grass, tall); *A. fatua*, L. (*see* Oat-grass, wild); *A. flavescens*, L. (*see* Oat-grass, yellow); *A. pratensis*, L. (*see* Oat-grass, narrow-leaved); *A. pubescens*, L. (*see* Oat-grass, downy); *A. sativa*, L. (*see* Oat)
Awn, 226
Axial skeleton, 408
Axil, 149
Axis (of seedling), 121
— vertebra, 410
Ayrshire cattle, 503
Azalea, 170
Azotobacter chroöcoccum, 40

BACKBONE, 408, 410
Bacon, 547
Bacteria, 39
Bacterial diseases, 405
Badger (*Meles taxus*), 611
Bagging-hook, 71, 96
Bakewell, Robert, 499, 574
Balaninus nucum (*see* Nut weevil)
Balm (*Melissa officinalis*, L.), 215
Bampton sheep, 525
Barberry rust (*see* Rust, black)
Bare fallow, 32, 101
Bark-beetles, 638
Barley (*Hordeum vulgare*, L.), 130, 145, 159, 261
— after wheat, 323
— bunt, 393
— composition of, 459
— crop, 24, 124, 311, 322
— as food, 457, 459, 461
— grass, meadow (*Hordeum pratense*, Huds.), 259
— wall (*H. murinum*, L.), 259
Barm, 384
Bar-point share, 49
Barrel, 408
Bars (of hoof), 419
Bartsia, red (*Bartsia Odontites*, Huds.), 268
Basalt, 7
Bases, 18, 39
Basic cinder or slag, 117
Bast, 145, 156
Bastard fallow, 313
Bates, Thomas, 494
Bats, 615
Beak (of Homoptera), 628
Beam, 48
Bean, 159, 191
— aphis (*Aphis rumicis*), 629
— crop, 191, 327
— as food, 457, 465
— hook, 97
Bean-seed beetle (*Bruchus rufimanus*), 620
Bearded, 226
Beardless, 226
Bedstraw, yellow (*Galium verum*, L.), 266

Beech (*Fagus sylvatica*, L.), 8, 135, 161
Beef, 510
Beef-making cattle, 493
Bees, 623
Beet (*Beta vulgaris*, L.), 135, 160, 170, 217
— sugar, 148, 217
— wild (*Beta maritima*, L.), 217
Beetles, 620
Bellis perennis, L. (*see* Daisy)
Belly, 408
Beneficial animals, 608
Bent grass, common or fine (*Agrostis vulgaris*, L.), 223, 237
— — creeping (*A. alba*, L., var. *stolonifera*), 236
— — marsh (*A. alba*, L.), 223, 237
Berkshire knot sheep, 521
— pigs, 538
Berry, 176
Beta vulgaris, L. (*see* Beet *and* Mangel)
Biennials, 160
Big bud, 645
Bilateral symmetry, 168
Bile, 429, 433
— duct, 429
Binder, 72
Bindweed, 135, 150
— larger (*Convolvulus sepium*, L.), 266
— lesser (*C. arvensis*, L.), 266
Bird-lice, 634
Birds, 615
— of prey, 617
— relation to agriculture, 616
'Birds' eyes' (*see* Speedwell)
Birdsfoot trefoil (*Lotus corniculatus*, L.), 200
— greater (*L. major*, Scop.), 201
Bistort, 43
— climbing (*Polygonum Convolvulus*, L.), 219
Bittersweet (see Nightshade, woody)

Blackberry (*Rubus fruticosus*, L.), 170
Blackbird, 618
Blackcap, 618
Black currant (*Ribes nigrum*, L.), 203, 370, 386
— — gall-mite (*Eriophyes ribis*), 645
Black-face mountain sheep, 523
Black fly, 629
— medick (*see* Trefoil)
— rot of cabbage, 405
— scab (*Chrysophlyctis endobiotica*), 402
— straw crop, 191
Blackthorn (*Prunus spinosa*, L.), 203
Bladder, 446
Bladder-worms, 653
Blade, of leaf, 155
Blood, 435, 550
— dried, 120
— system, 435
Bloom, waxy, 300
Blow-fly (*Sarcophaga carnaria*), 631
Bluebottle (*see* Cornflower)
Blue-grey cross, 502
Blue-stone (*see* Copper sulphate)
Boby screen, 88
Body (of plant), 149
— (of vertebra), 408
Bokhara clover (*see* Melilot)
Bone, composition of, 453
Bone-meal, 113
Bones, 113
Booth, Thomas, 494
Borage (*Borago officinalis*, L.), 216
Boragineæ, 215
Bordeaux mixture, 396, 399
Border Leicester sheep, 515
Bot flies, 632
Boulder clay, 6
Bracken, 3
Bract, 155, 208, 210
Brain, 450
Braincase, 410
Braird, 334

Bran, 457, 465
Branching form of green plants, 140, 142
Brassica napobrassica, Mill. (*see* Swede); *B. Napus*, L. (*see* Turnip); *B. oleracea*, L. (*see* Cabbage); *B. Rapa*, L. (*see* Rape); *B. sinapistrum*, L. (*see* Charlock)
Brasslets, 622
Brazil nut, 137
Breast-board, 150
Breast-bone, 411
Breathing (*see* Respiration)
Breeding, 468
— of poultry, 592
Breed records, 480
Breeds, 470
Brewers' grains, 457, 465
Briars, 150
British-Holstein cattle, 656
Briza media, L. (*see* Quaking grass)
Broadcasting, 285
Broad bean (*Faba vulgaris*, L.), 127
Broccoli, 183
Brome grass, barren (*Bromus sterilis*, L.), 256
— — hairy (*B. asper*, Murr.), 256
— — rye (*B. secalinus*, L.), 256
— — smooth (*B. racemosus*, L.), 256
— — soft (*B. mollis*, L.) 256
— — upright (*B. erectus*, Huds.), 257
Brome grasses (*Bromus* spp.), 159
Bronchial tubes, 442
Bronchitis, 442
Bronchus, 442
Bruchus rufimanus (*see* Bean-seed beetle)
Broom (*Cytisus scoparius*, Link.), 202
— rape (*Orobanche* spp.), 269
Bryonia dioica, L. (*see* White bryony)
Buckwheat (*Polygonum Fagopyrum*), 135, 159, 218
Bud, 149
Budding, 377
Buff-tip moth (*Pygæra bucephala*), 627
Bugle (*Ajuga reptans*, L.), 215
Bulb, 152
— mite (*Rhizoglyphus echinopus*), 646
Bullfinch, 618
Bunt (*Tilletia caries*, Tul.), 392
Burdock (*Arctium Lappa*, L.), 213
Burnet (*Sanguisorba officinalis*, L.), 202
Burs, 213
Bush fruit, 368, 370
— trees, 370
Butter, 567
Buttercups (*Ranunculus* spp.), 135, 150, 162, 264
Butter-fat, 558
Butterflies, 624, 625
Butter-making, 568
Butter-milk, 568
Butter ratio, 571
Butter-worker, 570
Butyric acid, 306

CABBAGE (*Brassica oleracea*, L.), 132, 160, 183
— aphis (*Aphis brassicæ*), 629
— butterfly (*Pieris* spp.), 627
— club-root (*see* Club-root)
— crop, 184, 345
— fly (*Anthomyia brassicæ*), 631
— as food, 457
— rust (*see* White rust)
— black rot (*Pseudomonas campestris*, Smith), 405
Caddis flies, 634
Cæcum, 427
Calcaneum, 417
Calcareous soil, 15
Calcium, 12
— cyanamide, 119
— nitrate, 119
Calf-flesh, 543, 544, 547

Calf-rearing, 508
Caltha palustris, L. (*see* Marsh Marigold)
Calyx, 162
Cambium, 149
Cambridge cheese, 581
— roller, 64
Campions (*Lychnis* spp.), 187
Canary grass (*Phalaris canariensis*, L.), 263
— seed, 263
Candytuft (*Iberis amara*, L.), 179
Cane sugar, 148
Canis vulpes (*see* Fox)
Canker of apple (*Nectria ditissima*, Tul.), 385
Cannon bone, 414
Capillaries, 437
Capillarity, 25
Capitate, 210
Capitulum, 210
'Caps,' 350
Capsella Bursa-pastoris DC. (*see* Shepherd's purse)
Capsule, 176
Caraway (*Carum Carvi*, L.), 206
Carbohydrates, 137, 431
Carbolic acid, 274
Carbon, 7, 35, 36
— assimilation, 158
— bisulphide, 642
— dioxide, 7, 34, 130
Carbonate of lime, 7, 12
Carbonic acid (*see* Carbon dioxide)
Carcases, composition, 543
Cardamine pratensis, L. (*see* Cuckoo flower)
Carduus spp. (*see* Thistle)
Carex spp. (*see* Sedges)
Carina, 168
Carlina spp. (*see* Thistle)
Carnation (*Dianthus caryophyllus*, L.), 150
— clover (*see* Crimson clover)
Carnivora, 610
Carpal bones, 413
Carpel, 162
Carpocapsa pomonella (*see* Codling moth)
Carpus, 413
Carrot (*Daucus Carota*, L.), 135, 145, 147, 160, 205
— blossom moth (*Depressaria daucella*), 627
— crop, 340
— fly (*Psila rosæ*), 631
— as food, 205
Cartilage, 409, 431, 454
Carts, 79
Cart-wheels, 79
Carum Carvi, L. (*see* Caraway); *C. Petroselinum*, Benth. (*see* Parsley *and* Sheep's Parsley)
Caryophyllaceæ, 187
Caryopsis, 175
Casein, 431
Castor oil seeds, 135
Catch crops, 181, 195
Catchflies (*Silene* spp.), 187
Catchwork system, 282
Caterpillar, 625
Cattle, breeds of, 492
— feeding and management of, 508
Caudal vertebræ, 410
Cauliflower, 183
— club-root (*see* Club-root)
— rust (*see* White rust)
Caustic lime, 13
Cavicornia, 421
Caving fork, 93
Cavings, 81
Cecidomyia destructor (*see* Hessian fly); *C. tritici* (*see* Wheat-midge)
Celery (*Apium graveolens*, L.), 135, 160, 206
— fly (*Tephritis onopordinis*), 631
Cells, 133, 134, 384, 654
Cellulose, 432
Centaurea Cyanus, L. (*see* Cornflower); *C. nigra*, L. (*see* Knapweed)
Centipedes, 646
Centrifugal drying machine, 569

Cephus pygmæus (*see* Corn saw-fly)
Cerastium spp. (*see* Sand-worts); *C. triviale*, Link. (*see* Mouse-ear chickweed)
Ceratophyllus fasciatus (*see* Rat flea)
Cereals, 135
Cerebro-spinal axis, 450
Cervical vertebræ, 410
Cestoda, 651
Ceutorhynchus sulcicollis (*see* Turnip-gall weevil)
Chaff, 227
— cutter, 89
Chain drills, 69
— harrows, 63
Chalcis flies, 622
Chalk, 4, 7, 42
Channel Islands cattle, 504
Charlock (*Brassica Sinapistrum*, Boiss.), 186
— spraying, 274
Cheddar cheese, 572
Cheese, 571
— press, 576
Cheese-making, 572
Cheese-mites (*Tyroglyphus siro* and *T. elatior*), 646
Cheimatobia brumata (*see* Winter moth)
Cheiranthus Cheiri, L. (*see* Wallflower)
Chenopodiaceæ, 216
Chenopodium spp. (*see* Goose-foot)
Chermes laricis (*see* Larch aphis)
Cherry (*Prunus Cerasus*, L.), 135, 161, 170, 367, 377
— sawfly (*Eriocampa limacina*), 623
Chest, 408
— vertebræ, 410
Chested, 261
Cheviot sheep, 522
Chickens, 599
Chickweed (*Stellaria media*, L.), 135, 187
Chicory (*Cichorium Intybus*, L.), 211
Chiroptera (*see* Bats)
Chit, 133
Chitin, 636
Chlorides, 34
Chlorine, 7, 35
Chlorophyll, 136, 142, 157, 435
— granules, 157
Chlorops tæniopus (*see* Ribbon-footed corn-fly)
Chobs. 83
Chondrin, 431, 454
Chromatin, 473
Chrysalis, 625
Chrysanthemum Leucanthemum L. (*see* Ox-eye Marguerite); *C. segetum*, L. (*see* Corn marigold)
Chrysophlyctis endobiotica (*see* Black scab)
Churn, 568
Churning, 568
Chyle, 449
Cichorium Intybus, L. (*see* Chicory); *C. Endivia*, L. (*see* Endive)
Cicuta virosa, L. (*see* Cowbane)
Cilia, 240
Cinquefoil (*Potentilla reptans*, L.), 203
Circulation of the blood, 437
Circulatory organs, 434
Clamp, 344
Classification of animals, 422, 609
— of plants, 178
— of soils, 14
Claviceps purpurea, Tul. (*see* Ergot)
Clavicle, 411
Clay, 2, 3, 11, 15, 19, 42, 103
Clean condition, 264
Cleaning land, 101, 284
Cleanliness (in dairy), 560
Cleavers (*see* Goosegrass)
Cleft-grafting, 379
Cleistogamous, 174
Cleveland bay, 484

Click beetles, 620
Climbing stems, 150
Clisiocampa neustria (*see* Lackey moth)
Clod crushers, 64
Clostridium butyricum (*see* Wet rot)
Clot, 436
Clotting (of blood), 435
Cloven hoof, 421
Clover (*Trifolium* spp.), 132, 159
— as food, 457, 462, 465
— crop, 349
— hay, 300
— sickness, 194, 350
— weevil (*Apion assimile*), 621
Club-root fungus (*Plasmodiophora brassicæ*, Wor.), 403
Clun Forest sheep, 531
Cluster-cup fungus, 388
Clydesdale, 486
Coach-horse, 485
Coagulation of blood, 435
Cochlearia Armoracia, L. (*see* Horse-radish)
Cockchafer (*Melolontha vulgaris*), 620
Cocking fork, 93
Cockroach, 633
Cocksfoot grass (*Dactylis glomerata*, L.), 230
Coco-nut, 137
— cake, 465
Cocoon, 635
Codlin moth (*Carpocapsa pomonella*), 627
Coffin bone, 415
Cole *or* Coleseed (*see* Rape)
Coleoptera, 620
Collar bone, 411
Collateral, 148
Collections of seeds, 277
Collier, 629
Colling, brothers, 494
Colon, 427
Colostrum, 553
Colourless corpuscles, 435
Colour of cattle, 493
— of flowers, 165, 172
Colour of soils, 4, 18, 29
Colt, 487
Coltsfoot (*Tussilago Farfara*, L.), 43
Columbine (*Aquilegia vulgaris*, L.), 169
Comfrey, common (*Symphytum officinale*, L.), 215
— prickly (*S. asperrimum*, Donn.), 161, 215
Compact form of animals, 140, 142
Compositæ, 155, 209
Composition of animal body, 452
— of soils, 10
Compound, leaf, 156
Compressors, hay, 79
Concentrated foods, 461
Condiment, 186, 202, 210, 252
'Condition' in soils, 112, 280
Condyle, 411
Conidiospore, 395
Conidium, 395, 401
Conium maculatum, L. (*see* Hemlock)
Connective tissue, 426, 454
Conopodium denudatum, Koch (*see* Earth-nut)
Constructive metabolism, 141
Convolvulaceæ, 266
Convolvulus arvensis, L. (*see* Bindweed, lesser); *C. sepium*, L. (*see* Bindweed, larger)
Copper sulphate, 274, 392, 399
Coprolites, 115
Cordon, 375
Core of apple, 177
Coriander (*Coriandrum sativum*, L.), 207
Corm, 152
Corn aphis (*Siphonophora granaria*), 630
— bunting, 617
— crops, 315
— gromwell (*Lithospermum arvense*, L.), 216
— mills, 91
— sawfly (*Cephus pygmæus*), 623

Corn-cockle (*Githago segetum*, Desf.), 188
Corn-crake, 617
Corn-marigold (*Chrysanthemum segetum*, L.), 213
Corolla, 162
Coronet, 415
Corpuscles, blood, 435, 550
Corylus Avellana, L. (*see* Hazel)
Cossar Ewart, 470
Cossus ligniperda (*see* Goat moth)
Costal cartilage, 411
Cost of crops, 357
Cotoneaster, 203
Cotswold sheep, 515
Cotton-cake, 457, 458, 465
Cotton-grass (*see* Cotton-sedges)
Cotton-sedges (*Eriophorum* spp.) 3, 228
Cotyledons, 127, 133
Couch-grass (*Triticum repens*, L.), 42, 152, 257
Coulommier cheese, 583
Coulter, 52
Covered yards, 109
Cowbane (*Cicuta virosa*, L.), 20[illegible]
Cow-grass (*Trifolium pratense perenne*, L.), 194
Cow-parsnip (*Heracleum Sphondylium*, L.), 207
Cowshed, 560
Cowslip (*Primula veris*, L.), 3, 270
Cow-wheat (*Melampyrum pratense*, L.), 268
Crab stock, 376
Cramming machine, 599
Cranefly (*Tipula oleracea*), 631
Cranesbill, cut-leaved (*Geranium dissectum*, L.), 265
— dove's-foot (*G. molle*, L.), 265
— meadow (*G. pratense*, L.), 266
— small-flowered (*G. pusillum*, L.), 265
Cranium, 410
Cratægus Oxyacantha, L. (*see* Hawthorn)
Cream, 557, 567
Cream cheese, 580-1
Creamometer, 557
Creeps, lamb, 533
Cremocarp, 205
Cress (*Lepidium sativum*, L.), 132
Crickets, 633
Crimson clover (*Trifolium incarnatum*, L.), 195
— crop, 347
Crocus (*Crocus* spp.), 152
Crop residue, 37
Crops, farm, 307
Cross-bred, 480
Cross-breeding, 476
Crosses, 480
Cross-fertilization, 165, 171
Crossing, 470, 476
Crossopus fodiens (*see* Shrew, water)
Cross-pollination, 165, 171
Crow, hooded (*Corvus corone*), 618
— garlic (*see* Onion, wild)
Crowfoot (*see* Buttercups)
Crown-grafting, 379
Cruciferæ, 135, 179
Cruciferous, 166
Crude sap, 147
Cruickshank, brothers, 494
Crushed bones, 113
Crust (of hoof), 419
Crustacea, 610
Cuboid bone, 417
Cuckoo (*Cuculus canorus*), 617
— flower (*Cardamine pratensis*, L.), 179
Cucumber (*Cucumis sativus*), 135, 204
Cucurbitaceæ, 204
Cucurbita maxima (*see* Pumpkin)
— *ovifera* (*see* Vegetable marrow)
Cud, 428
Culm, 222
Cultivating, 98
Cultivators, 62
Cuneiform bones, 413, 417

Cup-drills, **66**
Curd, 571
— knives, 574
— mill, 575
Currant (*Ribes* spp.), 150, 161, 203
— sawfly (*Nematus ribesiæ*), 623
Cuscuta Trifolii, Bab. (*see* Dodder)
Cuttings, 380
Cyclamen (*Cyclamen* spp.), 152
Cynara Scolymus, L. (*see* Artichoke)
Cynips kollari (*see* Marble gall fly)
Cynosurus cristatus, L. (*see* Dogstail grass)
Cyperaceæ, 227, 271
Cystopus candidus, Lev. (*see* Rust, white)
Cytisus scoparius, Link (*see* Broom)

DACTYLIS GLOMERATA, L. (*see* Cocksfoot grass)
Daddy-longlegs, 431
Dairy cattle, 493
— farming, 548
Dairying, 548
Daisy (*Bellis perennis*, L.), 156, 213
— rake, **94**
Damping off, 402
Damson, 367, 377
Dandelion (*Taraxacum officinale*, Wigg.), 146, 156, 212
Darnel (*Lolium temulentum*, L.), 250
Dart moth (*Agrotis segetum*), 627
Dartmoor sheep, 528
Darwin, Charles, 471
Darwinism, 471
Datura Stramonium, L. (*see* Thorn-apple)
Daucus Carota, L. (*see* Carrot)
Deadnettle, red (*Lamium purpureum*, L.), 215
— white (*L. album*, L.), **215**
Délaiteuse, **569**
Denitrification, 40
Density of soils, **22**
Denudation, 6
Depressaria daucella (*see* Carrot-blossom moth)
Depth of sowing, 278
Derbyshire gritstone sheep, **528**
Dermanyssus avium (*see* Hen-mite)
Destructive metabolism, **141**
Detritus, 6
Devon cattle, 497
— longwool sheep, **525**
Dew, 36
Dewberry (*Rubus cæsius*, L.), 203
Dew-claws, 422
Dexter cattle, 507
Dexter-shorthorn cattle, **507**
Dextrin, 432
Diamond-back moth (*Plutella cruciferarum*), 627
Dianthus Caryophyllus, L., (*see* Carnation)
Diaphragm, 408, **444**
— pillars of, 444
Diastase, 137
Dibble, 355
Dichogamous, 169
Dicotyledons, 156, **170**
Digestion, 432
— coefficient, 463
Digestive juices, 425, **429**
— organs, 425
Digging ploughs, 57
Digitalis purpurea, L. (*see* Foxglove)
Dilophus vulgaris (*see* Fever fly)
Diœcious flowers, 171
Diptera, 630
Disc drills, **68**
— plough, 58
Discontinuous variation, **475**

Diseases of crops, Chaps. xviii. and xxx.
— of poultry, 606
Dishley, 499, 514
Disintegration, 4
Disk, 210
Dispersal of seeds, 177
Dissolved bone-compound, 117
— bones, 117
Distributors, 69
Dock (*Rumex* spp.), 135
Docking, 218
Dodder (*Cuscuta* spp.), 150, 267
'Doddies,' 500
Dog-rose (*Rosa canina*, L.), 202
Dogstail grass (*Cynosurus cristatus*, L.), 231
Dolphin, 630
Dominant characters, 477
Dormant plant food, 19
Dorsal, 408
Dorset horn sheep, 526
Double-breasted plough, 61
Double-cut clover, 194
Double-furrow ploughs, 59
Doves, 618
Dragon flies, 634
Drags, 63
Drainage water, 24, 30
Drain gauges, 31
Draining, 43
Drains, 44
Draught chain, 49
Dressing poultry, 602
Dried blood, 120
Drilling, 285
Drills, 66
Driving horses, 483, 485
Drought, 283
Drupe, 176, 203
Drupel, 203
Ducklings, 600
Ducks, 588
Dung, 107
Durham cattle, 494
Dust, 35
Dusting flowers, 173
Dutch clover (*see* White Clover)

EAR, 223
— cockles, 648
Earth-nut (*Conopodium denudatum*, Koch), 151, 207
Earthworm, 9
Earwigs, 633
Echium vulgare, L. (*see* Viper's bugloss)
Eel-worm, beet (*Heterodera Schachtii*), 648
— root-knot (*H. radicicola*), 648
— stem (*Tylenchus devastatrix*), 648
— wheat (*T. scandens*), 648
Egg-cell, 164, 451
Egg-plant (*Solanum esculentum*, Dun.), 215
Eggs, 452
— marketing of, 604
— preservation of, 605
'Eggs-and-butter' (*see* Toad-flax)
Elaborated sap, 159
Elateridæ, 620
Elevator, 77, 299
Elm (*Ulmus campestris*, Sm.) 154
Embryo, 133, 451
Embryo-sac, 164
Emulsification, 433
Emulsion, 433
Endive (*Cichorium Endivia*, L.), 211
Endocardium, 437
Endopleura, 128
Endosmosis, 147
Endosperm, 134
Energy, 141
— of germination, 275
English cattle, 492
— sheep, 513
Ensilage, 303
Entomophilous, 165
Enzymes (*see* Ferments)
Epicalyx, 203
Epidermis, 157
Epigynous, 203
Erect stems, 150

Ergot (*Claviceps purpurea*, Tul.), 393
— (in horse), 418
Erinaceus europæus (*see* Hedgehog)
Eriocampa limacina (*see* Pear and Cherry sawfly)
Eriophorum spp. (*see* Cotton-sedges)
Ermine (*see* Stoat)
Erratic soils, 6, 8
Espalier, 375
Essential organs, 163
Essex pigs, 540
Euacanthus interruptus (*see* Hop cuckoo-fly)
Euphrasia officinalis, L. (*see* Eyebright)
Eupteryx solani (*see* Potato frog fly)
Evaporation, 25, 29, 30
Evolution, 470
Exalbuminous seeds, 134, 135
Excretion, 441, 445
Exhalation, 444
Exhausted soil, 19
Exmoor sheep, 528
Exoskeleton, 636
Exosmosis, 147
Exports of the farm, 545, 549
Exstipulate, 156
Extractives of blood, 550
Eyebright (*Euphrasia officinalis*, L.), 268
Eye of gooseberry, &c., 203
— of potato, 151

Faba vulgaris, L. (*see* Broad bean)
Fagging-hook, 71, 96
Fagus sylvatica, L. (*see* Beech)
Fall of the leaf, 161
Fallow, 32, 101
— bastard, 313
— crop, 310
False caterpillars, 637
— wireworms, 646
Farm crops, 307
— seeds, 275, 342-3

Farmyard manure, 107
Farrowing, 540
Fat, 137, 431, 455
— globules, 550
— hen (*see* Goosefoot)
Fattening of cattle, 511
— of fowls, 599
— of pigs, 541
Fatty foods, 458
'Feathering,' 486
Feeding, 142, 455
— value, 462
Felspar, 7, 11
Femur, 412, 416
Fennel (*Fœniculum vulgare*, Gaertn.), 206
Fenugreek (*Trigonella ornithopodioides*, DC.), 202
Fermentation, 109, 137, 301, 303, 306, 384, 433, 565
Ferments, 137, 433
Ferret, 611
Fertility of soils, 112
Fertilization, 164, 451
Fescue, fine-leaved (*Festuca tenuifolia*, Sibth.), 236
— hard (*F. duriuscula*, L.), 235
— meadow (*F. pratensis*, Huds.), 232
— red (*F. rubra*, L.), 236
— sheep's (*F. ovina*, L.), 234
— spiked (*F. loliacea*, Huds.), 233
— tall (*F. elatior*, L.), 233
— various-leaved (*F. heterophylla*, Lam.), 236
Fetlock, 418
Fever fly (*Dilophus vulgaris*), 632
Fibre, 461
Fibrin, 431, 436
— ferment, 436
Fibro-cartilages of hoof, 418
Fibrous roots, 145
Fibula, 416
Fieldfare, 618
Field slug (*Limax agrestis*), 609
— vole (*Microtus agrestis*), 613

Figwort (*Scrophularia nodosa*, L.), 268
Filament, 163
Filly, 487
Fine earth, 9, 17, 33, 38
Finger-and-toe, 308, 405
Finger-beam, 71
Fiorin (*see* Bent grass, creeping)
Fir, 3
Fishes, 609
Fish guano, 113
Flag (*see* Iris)
Flagellum, 398, 404
Flat system, 336
— worms, 649
Flavour, 456
Flax (*Linum usitatissimum*, L.), 188
Fleas, 631
Flesh, 454
Flesh-eating mammals, 610
Flesh-formers, 432
Flies, 630
'Floating' bone, 416
Flock book, 480
Floral diagram, 163
— receptacle, 162
Floret, 210
Flour, 134
Flower, 162
— leaf, 155, 162
— stalk, 162
Fluctuation, 475
Flukes (*Trematoda*), 650
Flycatchers, 618
Fly disease, 631
Foal, 487
Fœniculum vulgare, Gaertn. (*see* Fennel)
Fœtus, 451
Foliage-leaf, 155
Follicle, 176
Food-preparing machines, 89
Foods, 142, 455
— composition of, 457
— preparation of, 89
— mixtures of, 510, 512, 554
Foodstuffs, 430
Fool's parsley (*Æthusa Cynapium*, L.), 208
Forage crops, cruciferous, 344
— — leguminous, 346
Force feed drills, 69
Forest flies, 631
Forget-me-not (*Myosotis palustris*, With.), 170, 216
Fork, 92
Fossils, 7
Foster-mother, 596
Fowl-houses, 590
Fowls, 584
Fox (*Canis vulpes*), 610
Foxglove (*Digitalis purpurea*, L.), 268.
Foxtail, floating (*Alopecurus geniculatus*, L.), 240
— meadow (*A. pratensis*, L.), 238
— slender (*A. agrestis*, L.), 240
Fragaria vesca, L. (*see* Strawberry)
Frame, 49
Fraxinus excelsior, L. (*see* Ash)
Frit fly (*Oscinus frit*), 632
Frog, 609
— (of hoof), 420
Frontal bone, 411
Frost, 5
Fruit, 125, 132, 165, 174
— plantation, 368
— trees, 361, 367, 368
— varieties, 366, 367, 373
Fumariaceæ, 265
Fumitory, (*Fumaria* spp.), 265
Fungi of soil, 40
Fungus pests, 383
Funicle, 163
'Funny-bone,' 413
Furrows, forms of, 56
Furze (*see* Gorse)
Fusiform, 186

GAD FLIES, 631
Gains and losses of the blood, 450
— — — of the soil, 29

Galeopsis Tetrahit, L. (*see* Hemp nettle)
Galium Aparine, L. (*see* Goose grass); *G. verum*, L. (*see* Bedstraw, yellow)
Gall-bladder, 429
Gall flies, 623, 624
— mites, 645
Galloway cattle, 501
Galls, 620, 623
Gallus bankiva (*see* Jungle Fowl)
Game birds, 617
Gapes, 607
Gape-worm (*Syngamus trachealis*, 648
Garden fruit, 375
— soil, 41
Gas-lime, 642
Gastric gland, 428, 429
— juice, 429
Gastrophilus equi (*see* Horse bot-fly)
Gastropods, 609
Gelatin, 431, 454
Genus, 469
Geological maps, 4
Geology, 3
Geraniaceæ, 265
Geranium spp. (*see* Cranesbill); *G. dissectum*, L. (*see* Cranesbill, cut-leaved); *G. molle*, L. (*see* Cranesbill, dove's-foot); *G. Robertianum*, L. (*see* Herb Robert); *G. pusillum*, L. (*see* Cranesbill, small-flowered); *G. pratense*, L. (*see* Cranesbill, meadow)
Gerber milk-tester, 558
Germ, 133
Germ-cells, 473, 477
Germinal continuity, 473
Germinating capacity, 274
Germination, 127
Germ-plasm, 473
Gervais cheese, 584
Gestation, 481
Gherkin, 204
Giant sirex (*Sirex gigas*), 623
Gid, 652
Gills (of mushroom), 383
Githago segetum, Desf. (*see* Corn-cockle)
Glacier, 5
Glands, 425, 429
Glenoid cavity, 411
Globules, milk, 550
Glomes, 420
Glumes, 223
Gluten, 431
Glyceria aquatica, Sm. (*see* Sweet grass, reed); *G. fluitans*, Br. (*see* Sweet grass, floating)
Gnawing mammals (*Rodentia*), 611
Goat moth (*Cossus ligniperda*). 627
Goatsucker, 617
Good farming, 272, 644, 649
Gooseberry (*Ribes grossularia*, L.) 150, 161, 203, 270, 380
— and currant sawfly (*Nematus ribesiæ*), 623
— mildew, American, 395
Goosefoot (*Chenopodium* spp.), 216
Goosegrass (*Galium Aparine*, L.), 266
Gorse (*Ulex europæus*, L.), 132, 161, 169, 202
Goslings, 600
Gourd, 204
Gout fly, 632
Grade, 480
Grafting, 378
— clay, 380
— wax, 380
Grain, 224, 226
— crops, 178
Gramineæ, 221
Gramineous plants, 221
Granite, 7
Grant, Sir G. M., of Ballindalloch, 500
Grass as food, 462
— land, 279, 307
— orchards, 361

Grass seed, 226
Grasses, 135, 145, 150, 151, 156, 161
Grasshoppers, 633
Gravel, 17
Gray-lag goose (*Anser ferus*), 589
Grazing, 290
Green fly, 629
— manuring, 14, 43, 218
— soiling, 198, 215, 263
Greenfinch, 618
Gripping ploughs, 61
Grips, 61
Gristle, 409
Grooming, 445
Groundsel (*Senecio vulgaris*, L.), 213
Grub, 620, 622, 630
Grubbers, 62
Guano, 112
Guard cells, 158
Guernsey cattle, 505
Gullet, 425
Gulls, 417
Gum, 432
Gut, 425
Gypsum, 122

HACKNEY, 483
Hæmoglobin, 435, 443
— reduced, 444
Hair grass, tufted (*Aira cæspitosa*, L.), 258
— wavy (*A. flexuosa*, L.), 258
Hake and chain, 48
Half-standard trees, 368
Halteres, 630
'Hams,' 497
Hampshire Down sheep, 520
Hand tools, 92
Hardy fruit culture, 360
Hare (*Lepus europæus*), 612
Harmful animals, 608
Hariff (*see* Goosegrass)
Harrowing, 98
Harrows, 63
Harvest bug (*Leptus autumnalis*), 645
Harvesting, Chap. xvi., 71
Hatching of poultry, 593
Haulm, 190, 222
Haunch-bone, 412
Haustellata, 635
Haustoria, 267
Hawfinch, 618
Hawkbit (*Leontodon* spp.), 213
Hawkweed (*Hieracium* spp.), 213
Hawthorn (*Cratægus Oxyacantha*, L.), 202
Hay, as food, 462
— composition of, 457, 462, 465
— kicker, 76
— loader 299
— odour of, 301
Hayfield, 280
Haymaking, 296
Haymaking machine, 76
Haystack, 299
Hazel (*Corylus Avellana*, L.), 135, 170
Hazelled land, 335
Heart, 408, 436
Heat of the body, 445
— of the soil, 29
Heather, 3
Heavy horses, 481
— soils, 103
Hedera Helix, L. (*see* Ivy)
Hedgehog (*Erinaceus europæus*), 614
Hedge mustard (*Sisymbrium Alliaria*, Scop.), 179
— parsley (*Torilis nodosa*, L., and *T. anthriscus*, Huds.), 207
Hedge-slasher, 97
Heel-bone, 417
Heels (of hoof), 419
Hegelund system, 559
Height of horse, 484
Helianthus annuus, L. (*see* Sunflower); *H. tuberosus*, L. (*see* Jerusalem artichoke)
Hellebore, 643

Hemerobiidæ (*see* Lace-wing flies)
Hemiptera, 628
Hemlock (*Conium maculatum*, L.), 208
Hemp nettle (*Galeopsis Tetrahit*, L.), 215
Henbane (*Hyoscyamus niger*, L.), 214
Hen-mite (*Dermanyssus avium*), **645**
Hepatic vessels, **448**
Heracleum Sphondylium, L. (*see* Cow-parsnip)
Herbage of grass lands, **291**
Herb Robert (*Geranium Robertianum*, L.), 265
Herd book, 480
Herdwick sheep, **523**
Heredity, 472
Hereford cattle, **496**
Hesperis matronalis, L. (*see* Sweet Rocket)
Hessian fly (*Cecidomyia destructor*), **632**
Heterœcism, **389**
Heteroptera, 628
Hibernating mycelium, **398**
Hieracium spp. (*see* Hawkweed)
Highland cattle, **502**
High moulding of potatoes, **400**
Hilum, 127
Hip-girdle, 412
Hippuric acid, **446**
Hoar frost, **36**
Hock, **416**
Hoe, **94**
Hoed crops, **273**
Hoeing, **99**, **104**
Hog-weed (*see* Cow-parsnip)
Holcus lanatus, L. (*see* Yorkshire fog); *H. mollis*, L. (*see* Soft grass, creeping)
Holstein, British-, cattle, **656**
Homoptera, **628**
Honesty (*Lunaria* spp.), 179
Honey-bee (*Apis mellifica*), **623**
Honeycomb stomach, **427**
Honey-dew, **395**

Hooded crow, **618**
Hoof of horse, **416**, **418**
Hoofs and horns, **120**
Hooks, 96-7
Hop (*Humulus Lupulus*, L.), 150, 219
— aphis (*Phorodon humuli*), **629**
— crop, 125, 219
— cuckoo fly (*Euacanthus interruptus*), 630
— trefoil (*Trifolium procumbens*, L.), 196
'Hop' (*see* Trefoil)
Hordeum murinum, L. (*see* Barley, wall); *H. pratense*, Huds. (*see* Barley grass, meadow); *H. vulgare*, L. (*see* Barley)
Horehound (*Marrubium vulgare*, L.), 215
Hornblende, 11
Hornets, 622
Horns, 421
Horse, 407
— bot fly (*Gastrophilus equi*), 632
— chestnut (*Æsculus Hippocastanum*, L.), 135, 149, 156, **161**
— labour, 490
— worm (*Ascaris megalocephala*), 647
Horse-hoeing, **104**
Horse-hoes, 62
Horse-radish (*Cochlearia Armoracia*, L.), 152, 187
Horse-rake, 76, 298
Horses, breeds of, **481**
— feeding and management of, 487
Horse-tail, **43**
Host 267
House fly (*Musca domestica*), 631
— sparrow, 618
Hoven, **192**
Hover flies, **632**
Humble bees, **624**
Humerus, 411, **412**
Humulus Lupulus, L. (*see* Hop)

Humus, 10, 13, 15, 19, 37
Hunter, 482
Hyacinth, wild (or bluebell, *Scilla nutans*, Sm.), 152
Hybernia defoliaria (*see* Mottled umber moth)
Hybrid, 470
Hydrated, 12
Hydrocyanic acid, 643
Hydrogen, 18, 431
Hygroscopic awns, 252
Hylemyia coarctata (*see* Wheat-bulb fly)
Hylurgus piniperda (*see* Pine beetle)
Hymenoptera, 622
Hyoscyamus niger, L. (*see* Henbane)
Hypha, 384, 405
Hypoderma bovis (*see* Warble fly)
Hypogynous, 166
Hyponomeuta padella (*see* Small ermine moth)

IBERIS AMARA, L. (*see* Candytuft)
Ice, 5, 6
Ichneumon flies, 622
Identity to species, 276
Igneous rocks, 7
Iliac artery, 437
Ilium, 412
Imago, 635
Impregnation, 164, 451
Improvement of soils, 41
Impure blood, 443
Impurities of seed, 276
In-breeding, 474
Incompletæ, 170
Incubator, 593
Indian corn (*see* Maize)
Indigenous soil, 8
Indigestible fibre, 461
Inferior, 166
Inflammation, 442
Inflorescence, 173
Inhalation, 444
Innominate bone, 412
Insect, 165
— pollination, 171
Insect-eating mammals (*Insectivora*), 614
Insecticides, 640
Insectifuges, 640
Insects, 618
Insertion (of muscle), 424
Instep, 417
Integument, 163
Intercostal muscles, 444
Internode, 149
Intertillage, 104
Intestinal glands, 429
— juice, 429, 434
Intestine, 352, 408, 426, 427
Iris (*Iris Pseudacorus*, L.), 135
Irish cattle, 492
— sheep, 513
Iron, 12, 17
— pan, 27
— sulphate, 274
Irregular flower, 168
Irrigated land,
Isatis tinctoria, L. (*see* Woad)
Ischium, 412
Italian clover (*see* Crimson clover)
Itch, 644
Ivy (*Hedera Helix*, L.), 150
Ixodes ricinus (*see* Sheep tick)

JACKDAW, 617
Jaws (of insects), 634
Jay, 617
Jersey cattle, 504
Jerusalem artichoke (*Helianthus tuberosus*, L.), 151, 212
Jointed-limbed animals, 609
Joint in grasses, 222
— oil, 414
Juglans regia, L. (*see* Walnut)
Jugular vein, 440
Juncaceæ, 227, 271
Juncus communis, Meyer), (*see* Rush, common),
Jungle fowl (*Gallus bankiva*), 584

MAH

Mahaleb stock, 377
Maintenance diet, 455
Maize (*Zea Mays*, L.), 130, 158, 263
— as food, 457, 465
Malaria, 631, 634
Mallard (*Anas boschas*), 588
Mallophaga, 634
Malt-culms, 465
— sugar, 137
Malting, 136
Mammalia, 407, 422, 610
Mammary glands, 548
Mandible, 411
Mandibulata, 635
Mange, 644
Mangel (*Beta vulgaris*, L.), 135 152, 160, 217
— crop, 125, 217, 336
— fly (*Pegomyia betæ*), 632
— as food, 460
Manna grass, floating (*see* Sweet grass, floating)
Manual delivery reaper, 71
Manures, 105, 291, 463
— for special crops, 123, 286, 290, 337, 356, 366, 372
Manurial value of food, 466
Manuring, 105
Manyplies, 427
Maple (*Acer campestre*, L.), 135
Marble, 7
— gall fly (*Cynips kollari*), 623
Marjoram (*Origanum onites*, L.), 215
Marl, 4, 15, 42
Marrubium vulgare, L. (*see* Horehound)
Marsh marigold (*Caltha palustris*, L.), 169, 264
Marling, 42
Martins, 618
Mating of poultry, 592
Matricaria inodora, L. (*see* Scentless may-weed)
Matthiola spp. (*see* Stock)
Maxillary bone, 411
Maximum temperature, 129
May flies, 634

MIC

McCombie, Wm., of Tillyfuir, 500
Meadow, 279
— foxtail (*see* Timothy grass)
— vetchling (*Lathyrus pratensis*, L.), 202
Meadow grass, annual (*Poa annua*, L.), 241
— — rough-stalked (*P. trivialis*, L.), 223, 242
— — smooth-stalked (*P. pratensis*, L.), 223, 242
— — wood (*P. nemoralis*, L.), 223, 243
Meadow-sweet (*Spiræa Ulmaria*, L.), 203
'Mealy-mouthed' cattle, 505
Measly pork, 653
Medicago lupulina, L. (*see* Trefoil); *M. sativa*, L. (*see* Lucerne)
Medulla oblongata, 450
Melampyrum pratense, L. (*see* Cow-wheat)
Meles taxus (*see* Badger)
Meligethes æneus (*see* Turnip-blossom beetle)
Melilot, white (*Melilotus alba*, Lank.), 201
— yellow (*M. officinalis*, L.), 201
Melissa officinalis, L. (*see* Balm)
Mellow soil, 5, 16
Melolontha vulgaris (*see* Cockchafer)
Melon, 204
Mendel, 476
Mendelism, 475
Mentha viridis, L. (*see* Mint)
Mericarp, 205
Mesentery, 427
Mesophyll, 157
Metabolic staircase, 142
Metabolism, 140, 424
Metacarpal bones, 414
Metacarpus, 414
Metamorphosis, 635
Metatarsal bones, 417
Metatarsus, 417
Metœcism, 389
Mica, 7, 11

Micaceous sand, 11
Micropyle, 163
Microtus agrestis (*see* Field vole)
Middle white pigs, 537
Mildew, 295
Milk, 548
— cistern, 548
— composition, 552
— fountains, 551
— record, 555
— recorder, 556
— register, 553
— strainer, 561
— sugar, 552
— vein, 551
Milking, 559
Millipedes, 646
Mills, corn, 91
Mimulus moschatus, Dougl. (*see* Musk)
Mineral manures, 114
— matter, 10, 19
— phosphates, 114
Minimum temperature, 129
Mint (*Mentha viridis*, L.), 153, 215
Mites, 644
Moisture, 23, 129
Mole (*Talpa europæa*), 615
Molluscs, 609
Mongrel, 470
Monocotyledons, 156, 170
Monœcious flowers, 171
Moorland pan, 27
Mosquitoes, 631
Moths, 624, 625
Mottled umber moth (*Hybernia defoliaria*), 627
Mould-board, 50
Moulds, 384
Mountain sheep, 513
Mouse, field (*Mus sylvaticus*), 613
— harvest (*M. messorius*), 613
— house (*M. musculus*), 613
Mouse-ear chickweed (*Cerastium triviale*, Link), 187
Mowing, 296
Mowing machines, 74
Mulch, 26, 99
Mulching, 29, 366
Mule, 470
Mullein (*Verbascum Thapsus*, L.), 268
Multiple plough, 60
Muriate of potash, 121
Muridæ, 612
Musca domestica (*see* House fly)
Muscle, 423
Muscular contraction, 424
Muscular system, 423
Mus decumanus (*see* Rat, brown); *M. messorius* (*see* Mouse, harvest); *M. musculus* (*see* Mouse, house); *M. rattus* (*see* Rat, black); *M. sylvaticus* (*see* Mouse, field)
Mushroom (*Agaricus campestris*), 383
Musk (*Mimulus moschatus*, Dougl.), 268
Mustard, 132; black (*Sinapis nigra*, L.), white (*S. alba*, L.)
— beetle (*Phædon betulæ*), 620
— crop, 14, 186 346
Mustelidæ, 611
Mutation, 475
Mutton, 534
Mycelium, 384
Myosin, 431, 454
Myosotis spp. (*see* Scorpion grass); *M. palustris*, With. (*see* Forget-me-not)
Myriapods, 646
Mytilaspis pomorum (*see* Apple mussel scale)

Nag, 483
Nagana, 631
Napiform, 186
Nasturtium officinale, L. (*see* Watercress)
Native plant growth, 3
Natural selection, 472
Navicular bone, 417
'Navicular' bone, 416
— disease, 416

Neck, **408**
— vertebræ, 410
Nectar, **165**
Nectar-cover, **165**
Nectar-gland (*see* Nectary), 165
Nectar-guide, **170**
Nectarine, **377**
Nectria ditissima, Tul. (*see* Canker of apple)
Nemathelmia, **646**
Nematus ribesiæ (*see* Gooseberry and Currant sawfly)
Nerves, **450**
Nervous system, **450**
Neufchâtel cheese, **583**
Neural canal, **408**
Neuroptera, **633**
Newts, **609**
Nicotiana Tabacum, L. (*see* Tobacco)
Night-flutterer, **627**
Nightshade, deadly (*Atropa Belladonna*, L.), **214**
— woody (*Solanum Dulcamara*, L.), **214**
Nitragin, **40**
Nitrate of lime, **39**
— of soda, 118
Nitrates, 13, **30**, 31, 35, 39
Nitric acid, **36**, 37, 38
Nitrification, **38**
Nitrites, 35, **39**
Nitrobacter, **39**
Nitrococcus, **39**
Nitrogen, 7, 19, **34**
— starvation, **456**
Nitrogenous excretion, 445
— foods, **431**
— manures, **118-21**
— waste, **446**
Nitrosomonas, **39**
Nitrous acid, **39**
Node, **149**
Nodules, **39**, **200**
Non-ruminantia, **423**
Nonsuch (*see* Trefoil)
Norfolk rotation, **309**
— sheep, **521**
North Devon cattle, **497**
Nucellus, **163**
Nuthatch, **617**
Nutlets, **215**
Nuts, **175**
Nut weevil (*Balaninus nucum*), **621**

Oak (*Quercus* spp.), 3, **159**
Oak-apples, **623**
Oat (*Avena sativa*, L.), 159, **262**
— crop, 24, 124, 311, 321
— as food, 457, 459, 465
Oat-grass, downy (*Avena pubescens*, L.), **246**
— false or tall (*A. elatior*, L., or *Arrhenantherum avenaceum*, Beauv.), **246**
— narrow-leaved (*A. pratensis*, L.), **247**
— yellow or golden (*A. flavescens*, L.), **244**
— wild (*A. fatua*, L.), **247**
Oat-husk, **262**
Oatmeal, **262**
Occipital condyles, **410**
Odontoid process, **410**
Odour of flowers, **165**
— of hay, **301**
Œnanthe fistulosa, L. (*see* Water dropwort)
Œsophagus, **425**
Œstrus ovis (*see* Sheep's nostril fly)
Offal, **479**
Oil, **137**
— cakes, **189**, **458**
— engine, **85**
— in food, **458**, **459**
Olecranon process, **413**
Olein, **455**
Omasum, **427**
One-way ploughs, **59**
Onion (*Allium Cepa*, L.), **135**, **145**, **151**, **162**, **170**, **220**
— couch (*see* Oat-grass, tall)
— fly (*Anthomyia ceparum*), **632**
— wild (*Allium vineale*, L.), **221**

Onobrychis sativa, L. (*see* Sainfoin)
Ononis spinosa, L. (*see* Rest-harrow)
Onopordon Acanthium, L. (*see* Thistle)
Oogonium, 401
Oospore, 401
Opposite, 156
Optimum temperatures, 28, 129
— water content of soil, 24
Orchard grass (*see* Cocksfoot grass)
Organic manures, 106, 120, 121
— matter, 9, 13, 19, 35
— nitrogen, 32, 38
Origanum onites, L. (*see* Marjoram)
Origin (of muscle), 424
Ornithopus sativus, Brot. (*see* Serradella)
Orobanche spp. (*see* Broom-rape)
Orobanchaceæ, 269
Orthoptera, 632
Oscinis frit (*see* Frit fly)
Os innominatum, 412
Osmosis, 147
Ovary, 163
Ovipositor, 622, 630
Ovule, 163
Ovum, 451
Owls, 617
Ox, skeleton of, 420
— warble fly (*Hypoderma bovis*), 632
Ox-eye Marguerite (*Chrysanthemum Leucanthemum*, L.), 213
Oxford Down sheep, 518
Oxidation, 143
Oxide of iron, 17, 18, 108, 544
Oxides, 11, 17
Oxygen, 7, 34, 130
Oxyhæmoglobin, 443

PALE, 224
Palisade cells, 157
— worms, 647
Palmate, 156
Palm-bones, 414
Palmitin, 455
Palm-nut cake, 465
Pancreas, 430
Pancreatic duct, 430
— juice, 434
Panicle, 223
Pans, 27
Pansy (*Viola tricolor*, L.), 170
Papaveraceæ, 265
Papaver Rhœas, L. (*see* Poppy); *P. somniferum*, L. (*see* Poppy, opium)
Papilionaceous, 168
Pappus, 177, 212
Paradise stock, 376
Paraffin, 642
Parasite, 385
Parietal bone, 411
Paring and burning, 42
Paris green, 643
Parsley (*Carum Petroselinum*, Benth.), 206
Parsnip (*Pastinaca sativa*, Benth.), 135, 145, 147, 160, 206
— crop, 340
— fly (*Tephritis onopordinis*), 631
— as food, 206
Pastern, 416
Pasteurisation of milk, 567
Pastinaca sativa, Benth. (*see* Parsnip)
Pasture, 279, 289
Patella, 416
Paunch, 427
Pea (*Pisum sativum*, L.), 128, 130, 150, 159
— crop, 190, 330
— as food, 457, 459, 465
— hook, 71, 97
— seed, 128
Peach, 377
Pear (*Pyrus communis*, L.), 161, 361, 366, 373, 375, 377
— grass orchard, 361

Pear leaf blister-mite (*Eriophyes pyri*), 645
— sawfly (*Eriocampa limacina*), 623
Pearl barley, 262
Peat, 14, 22
— moss litter, 109
Peaty pan, 27
Pectin, 432
Pedigree, 480-1
Peduncle, 162
Pegomyia betæ (*see* Mangel fly)
Pelargonium, 170
Pelvis, 412
Peppercorns, 648
Pepsin, 433
Peptic glands, 428
Peptones, 433
Perennial, 161
Perianth, 163
Pericardial fluid, 436
Pericardium, 436
Perigynous, 170
Perissodactyla, 423
Peristaltic contraction, 430
Perithecium, 394, 396
Peritoneum, 427
Permanent grass, 125, 279, 295, 658
Peruvian guano, 112
Pests, animal, 608
Petal, 162
Petiole, 156
Petrol engines, 86
Petroleum, 642
Phædon betulæ (*see* Mustard beetle)
Phalaris canariensis, Moench. (*see* Canary grass)
Pharynx, 425
Pheasant's-eye (*Adonis autumnalis*, L.), 264
Phorodon humuli (*see* Hop aphis)
Phleum pratense (*see* Timothy grass)
Phosphates, 13, 30, 113, 123
Phosphoric acid, 12, 17, 19, 30, 107
Phyllotreta nemorum (*see* Turnip flea beetle)
Phylloxera vastatrix, 628
Physiology, 407
Phytophthora infestans, De Bary (*see* Potato disease)
Pickling seed corn, 316, 392
Piercing insects, 635
Pieris spp. (*see* White cabbage butterflies)
Pig, breeds of, 535
— feeding and management of, 540
— skeleton of, 422
Pigeons, 618
Pig-nut (*see* Earth-nut)
Pileus, 383
Pimpernel, scarlet (*Anagallis arvensis*, L.), 270
Pin-bone, 412
Pine beetle (*Hylurgus piniperda*), 621
— sawfly (*Lophyrus pini*), 623
Pinnate, 156
Pipits, 617
Pirls, 530
Pisiform bone, 413
Pistil, 162
Pistillate flowers, 171
Pisum sativum, L. (*see* Pea)
Pitchfork, 93
Placenta, 451
Placentation, free central, 270
Plantagineæ, 270
Plantain (*Plantago* spp.), 135, 146, 156, 161
— common (*P. lanceolata*, L.), 270
— greater (*P. major*, L.), 270
— hoary (*P. media*, L.), 271
Plantar cushion, 418
Plant bugs, 628
— lice, 628
Plant-food, 18-20, 131
Planting fruit-trees, 362, 367
— mixed fruit, 368, 370
Plantlet, 164
Plasma, 435
Plasmodium, 405

PLA

Plasmodiophora Brassicæ, Wor., 403
Platyhelmia, **649**
Pleura, 442
Pleurisy, 442
Pleuropneumonia, **443**
Ploughing, 52-7, **98**
Plough-pan, 27
Ploughs, 47-61
Ploughshares, 49
Plough wheels, 51
Plovers, 43, 617
Plum (*Prunus domestica*, L.), 161, 367, 373, 377
— aphis (*Aphis pruni*), **630**
Plumule, 128
Plusia gamma (*see* Silver Y-moth)
Plutella cruciferarum (*see* Turnip diamond-back moth)
Pneumogastric nerve, 450
Pneumonia, 443
Poa annua, L. (*see* Meadow grass, annual); *P. nemoralis*, L. (*see* Meadow grass, wood); *P. pratensis*, L. (*see* Meadow grass, smooth-stalked); *P. trivialis*, L. (*see* Meadow grass, rough-stalked)
Poached land, **323**
Pod, 176
Poisonous plants, 208, 272
Polecat (*Putorius fœtidus*), **611**
Pollard, **465**
Polled, 421
Pollen, **163**
— grain, **163**, **164**
— tube, **164**
Pollination, **164**
Polygonaceæ, 218
Polygonum Aviculare, L. (*see* Knot-grass); *P. Convolvulus*, L. (*see* Bistort, climbing); *P. Fagopyrum*, L. (*see* Buckwheat)
Pome, **203**
Pont l'Evêque cheese, 582
Pony, **484**
Pooking fork, **98**

PRO

Poor man's weather-glass (*see* Pimpernel, scarlet)
Poor soils, 41
Poppy (*Papaver Rhœas*, L.), **135**, 265
— opium (*P. somniferum*, L.), 265
Pore space, 22
Porlock sheep, 528
Portal vein, **438**
Posterior, 408
— vena cava, 439, **446**, 448
Potash, 12, 17, 19, 30,
— manures, 121
Potato (*Solanum tuberosum*, L.), 135, 151, 155, 162, 214
— as food, 457, 465
— crop, 351
— disease (*Phytophthora infestans*, De Bary), **396**
— frog fly (*Eupteryx solani*), 629
— planters, **69**
— raising plough, **61**
— wet rot, 405
Potentilla Anserina, L. (*see* Silverweed); *P. reptans*, L. (*see* Cinquefoil)
Poultry, 584
— keeping, 584
Precocious plants, **212**
Premaxillary bone, **411**
Prenasal ossicle, 422
Prepotency, **474**
Pressers, **64**
Presses, **79**
Prickles, **177**
Primrose (*Primula vulgaris*, Huds.), 152, 270
Primulaceæ, 270
Proboscis, 622, 625, 630, 634
Prone, **413**
Propagation of fruit, **376**
Protandrous, **169**
Proteins (proteids or albuminoids), 138, **431**
Proteolytic, **138**, 433
Protogynous, **169**
Protoplasm, **140**

Protozoa, 40, 653
Proud wheat, 263
Prunella vulgaris, L. (*see* Self-heal)
Pruning, 364, 367, 370, 375-6
Prunus Cerasus, L. (*see* Cherry); *P. spinosa*, L. (*see* Blackthorn)
Psalterium, 427
Pseudomonas campestris, Smith, 405
— *destructans*, Potter, 405
— *radicicola*, 39
Psila rosæ (*see* Carrot fly)
Psoroptes communis (*see* Scab, sheep)
Psylla mali (*see* Apple sucker)
Ptyalin, 433
Pubis, 412
Puccinia graminis, Pers. (*see* Rust, black); *P. glumarum*, Eriks. et Henn. (*see* Rust, yellow)
Pulmonary circulation, 439
Pulpers, 91
Pulse, 439
— crops, 327
Pulses, 190
Pulvinaria ribesiæ (*see* Woolly currant scale)
Pumice, 7
Pumpkin (*Cucurbita maxima*), 130, 204
Punch, Suffolk, 487
Pupa, 625, 635
Pure blood, 443
Pure-bred, 479
Purging flax (*Linum catharticum*, L.), 190
Purples, 648
Putorius erminea (*see* Stoat); *P. fœtidus* (*see* Polecat); *P. vulgaris* (*see* Weasel)
Pygæra bucephala (*see* Buff-tip moth)
Pylorus, 426
Pyramid trees, 370
Pyrethrum, 643
Pyrus Malus, L. (*see* Apple)
Pythium, 402

Quaking grass (*Briza media*, L.), 259
Quadrant head, 49
Quality of hay, 301
— of oilcakes, 458
Quarters, of hoof, 419
— of horse, 412
— of udder, 548
Quartz, 7
Quercus spp. (*see* Oak)
Quicklime, 13, 42

Rabbit (*Lepus cuniculus*), 612
Race, 469
Raceme, 196
Rachis, 300
Radial, 145
— symmetry, 166
Radicle, 128
Radish (*Raphanus sativus*, L.), 132, 145, 147, 186
Radius, 412
Ragged Robin (*Lychnis Flos cuculi*, L.), 187
Rain, 9, 34
Rake, 93
Ranunculaceæ, 264
Ranunculus spp. (*see* Buttercups)
Rape (*Brassica rapa*, L.), 182
— club-root (*see* Club-root)
— crop, 14, 182, 344
Rape-cake, 457, 465
Raphanus sativus, L. (*see* Radish)
Raspberry (*Rubus Idæus*, L.), 154, 161, 372, 374, 383
Rat, black (*Mus rattus*), 612
— brown (*M. decumanus*), 613
— flea (*Ceratophyllus fasciatus*), 631
Ray, 210
Real value of seeds, 277
Reapers, 71
Reaping, 96
— hook, 96
Rearing of poultry, 593
Recessive characters, 477

Rectum, 427
Red clover (*Trifolium pratense*, L.), 193
— corpuscle, **435**
— currant (*Ribes rubrum*, L.), 203, 370, 381
— maggot, 632
— poll cattle, 499
— shank (*see* Knot-grass)
— spider, 645
Reed, 427
Refrigerator, milk, **562**
Regions of body, 407
Register, milk, 553
Regular flower, 166
Renal artery, 446
— vein, 446
Rennet, 428, 433, 571
— stomach, 427, 428
Rennin, 433
Replum, 176
Reproduction, 451
Reproductive organs, **451**
Reptiles, 609
Respiration, 143, 158, 425, 443
Respiratory organs, 442
— movements, 444
Rest-harrow (*Ononis spinosa*, L.), 202
Resting spore, **403**
Retentive power of soils, **30**
Reticulum, 427
Reversion, 473
Rheum hybridum, Murr. (*see* Rhubarb)
Rhinanthus Crista-galli, L. (*see* Yellow rattle)
Rhizome, 152
Rhubarb (*Rheum hybridum*, Murr.), 218
Ribbon-footed corn-fly (*Chlorops tæniopus*), 632
Ribes Grossularia, L. (*see* Gooseberry)
— *nigrum*, L. (*see* Black currant)
— *rubrum*, L. (*see* Red currant)
Ribesiaceæ, 203
Rib-grass, or Ribwort (*see* **Plantain, common)**
Ribs, 411
Rice-meal, 457, 465
Ridge system, **336**
Ridge and furrow system, 281
Ridging plough, 61
Riding horse, 483
Ripened cream, 565
Robber flies, 632
Robin, 618
Rock, 4, 7
— crystal, 7
Rock-salt, 7
Rollers, 64
Rolling, **98**
Romney Marsh sheep, **516**
Rook, 618
Root, 38, 128, 130, 139, 144
— crops, 124, 160, 178, 332
— nodules, 39
— parasites, 268, 270
— pruning, 375
Root-cap, 145
Root-hairs, 131, 145
'Rooting,' of swine, 541
Rootstock, 152
Rosa canina, L. (*see* Dog-rose)
Rosaceæ, 202
Roscommon sheep, 531
Rose (*Rosa* spp.), 154, 156, 170
Rosemary (*Rosmarinus officinalis*, L.), 215
Rosette plants, 156
Rotary screen, 88, 291, 543
Rotation grasses, 125, and *see* 'Seeds'
— of crops, 308
Rothamsted experiments, 31
Round worms, 646
Roup, 607
Rubiaceæ, 266
Rubus cæsius, L. (*see* Dewberry); *R. fruticosus*, L. (*see* Blackberry)
— *Idæus*, L. (*see* Raspberry)
Rumen, 427

Rumex spp. (*see* Dock *and* Sorrel); *R. Acetosa*, L. (*see* Sorrel, common); *R. Acetosella*, L. (*see* Sorrel, sheep's)
Ruminantia, 423
Rumination, 428
Runner, 151
Running roots, 152
— water, 6
Runts, 498
Rush, common (*Juncus communis*, Meyer), 227
Rushes, 3, 43
Rust, black (*Puccinia graminis*, Pers.), 386
— yellow (*P. glumarum*, Eriks. et Henn.), 390
— white (*Cystopus candidus*, Lev.), 400
Rye (*Secale cereale*, L.), 159, 262
— crop, 326
— ergot (*Claviceps purpurea*, Tul.), 393
— as food, 457
Rye-grass, Italian (*Lolium italicum*, A. Br.), 250
— perennial (*L. perenne*, L.), 247
Ryeland sheep, 524

SACCHAROMYCES CEREVISIÆ (*see* Yeast)
Sacral vertebræ, 410
Sacrum, 410
Saffron, meadow (*Colchicum autumnale*, L.), 221
Sage (*Salvia officinalis*, L.), 215
Sainfoin (*Onobrychis sativa*, L.), 132, 161, 198
— crop, 24, 348
Salad plants, 187, 204, 211, 212, 214, 217, 220
Saliva, 425, 433
Salivary glands, 425, 429
Salix spp. (*see* Willow)
Salt, 35, 121, 274
Salts, 18
Salvia officinalis (*see* Sage)
Sand, 3, 10, 15, 19
Sandstone, 7
Sandworts (*Cerastium* spp.), 187
Sanguisorba officinalis, L. (*see* Burnet)
Saprophyte, 385
Sarcophaga carnaria (*see* Blow fly)
Sarcoptes lævis, 645
— *mutans*, 645
— *scabiei* (*see* Scab, head)
Savoury herbs, 206, 215
Sawflies, 622, 623
Scab, head (*Sarcoptes scabiei*), 644
— sheep (*Psoroptes communis*), 644
Scale insects, 630
— leaf, 155
Scaly roots, 152
Scandix Pecten-Veneris, L. (*see* Shepherd's needle)
Scaphoid bone, 413
Scapula, 411
Scarifiers, 62
Scarious, 270
Scarlet clover (*see* Crimson clover)
Scentless mayweed (*Matricaria inodora*, L.), 213
Schizoneura lanigera (*see* Woolly aphis)
Scientific names, 469
Scilla nutans, Sm. (*see* Hyacinth)
Scion, 378
Sclerotium, 393
Scooping bone, 422
Scorpion grass (*Myosotis* spp.), 216
Scotch cattle, 492
— hands, 570
— sheep, 513
Scratching-shed, 591
Screenings, 272
Screens, 88
Scrophularia nodosa, L. (*see* Figwort)

Scrophularineæ, 268
Scufflers, 62
Scutellum, 133
Scythe, 71, 94
Seaweed, 121
Secale cereale, L. (*see* Rye)
Secretions, 429
Sedentary soil, 8
Sedges (*Carex* spp.), **3**, **43**, 135, 154, 228
Seed, 125, 174
Seed-barrow, 285
Seed-bed, 284
Seeding, 128
Seed-leaves, 127, 162
Seedling, 128
Seed-mixtures, 288
'Seeds,' hay, 295, 302
— crop, 349
Selection of poultry, 592
— of seeds, 274
Self-delivery reaper, 72
Self-fertilization, 165, 174
Self-heal (*Prunella vulgaris*, L.), 215
Self-pollination, 165, 174
Semilunar valves, 437, 439
Senecio vulgaris, L. (*see* Groundsel)
Sense organs, 451
Sepal, 162
Separators, cream, 563
Serradella (*Ornithopus sativus*, Brot.), 292
Serum, 436
Sesamoid bones, 414
Sessile, 156
Setaceous, 222
Sets (of potato), 151, 214
Setting milk, 562
Sewage, 247
Sexual reproduction, 165, 451
Shallot (*Allium ascalonicum*, L.), 221
Shaping board, 602
Sheep, breeds of, 513
— farming, 531
— feeding and management of, 531

Sheep, skeleton of, 422
— tick (*Ixodes ricinus*), 645
Sheep's nostril fly (*Œstrus ovis*), 632
Sheep's parsley (*Carum Petroselinum*, Benth., var.), 206
Shellfish, 609
Shepherd, 532
Shepherd's needle (*Scandix Pecten-Veneris*, L.), 207
Shepherd's purse (*Capsella Bursa-pastoris*, DC.), 145, 400
— weather-glass (*see* Pimpernel, scarlet)
Shin bone (*see* Tibia)
Shire horse, 485
Shock, 318
Shoddy, 120
Shoot, 128, 130, 139
Short dung, 110
Shorthorn cattle, 493
Shortwool sheep, 513
Shoulder-blade, 411
Shoulder-girdle, 411
Shovel, 92
Shrew, common (*Sorex vulgaris*), 615
— lesser (*S. minutus*), 615
— water (*Crossopus fodiens*), 615
Shrew-mouse (*see* Shrew)
Shropshire sheep, 520
Sickle, 71, 96
Side-cap, 50
Side-delivery rake, 297
Sieves, 88
Silage, 303
Silene spp. (*see* Catchflies)
Silica, 7, 11
Silicate of alumina, 12
Silicula, 176
Siliqua, 176
Silo, 303
Silt, 17
Silverweed (*Potentilla Anserina*, L.), 202
Silver Y-moth (*Plusia gamma*), 626
Simple leaf, 156

SIN

Sinapis alba, L. (*see* Mustard, white)
Single-cut clover, **194**
'Singling,' **341**
Siphonophora granaria (*see* Corn aphis)
Sirex gigas (*see* Giant sirex)
Sisymbrium Alliaria, Scop. (*see* Hedge mustard)
Sium spp. (*see* Water parsnip)
Skeleton, **408**
Skim coulter, **52**
— milk, 552
Skin, **445**
Skirting steak, **444**
Skull, 410
Skylark, **617**
Slade, **49**
Slaked lime, **13**
Slasher, **97**
Slate, **4**
Sleep of plants, **192**
Sliding head, **49**
Sloe (*see* Blackthorn)
Slugs, **609**
Small black pigs, **540**
— ermine moth (*Hyponomeuta padella*), **627**
— intestine, 426
— white pigs, **537**
Smother-flies, **628**
Smut, barley (*Ustilago nuda*, Jens., and *U. tecta*, Jens.), **390**
— oats (*U. avenæ*, Jens.), 390
— wheat (*U. tritici*, Jens.), 390
Snails, **609**
Snaith, **94**
Snakes, **609**
Snakeweed (*see* Bistort)
Snapdragon (*Antirrhinum majus*, L.), 268
Soda, **17**
Sodium arsenite, **274**
Soft cheese, 580
— grass, creeping (*Holcus mollis*, L.), **260**
— palate, **425**
Soil, **1**

SPL

Solanaceæ, **213**
Solanum Dulcamara, L. (*see* Nightshade, woody); *S. esculentum*, Dun. (*see* Egg-plant); *S. Lycopersicum*, L. (*see* Tomato); *S. tuberosum*, L. (*see* Potato)
Sole (of hoof), **419**
Solution, **6**
Soma, **473**
Sonchus spp. (*see* Sow-thistle)
Soot, 120, **642**
Sorex minutus (*see* Shrew, lesser); *S. vulgaris* (*see* Shrew, common)
Sorghum (*Sorghum saccharatum*, Mœnch.), **263**
Sorrel (*Rumex* spp.), **135**
— common (*R. Acetosa*, L.), 218
— sheep's (*R. Acetosella*, L.), 218
Sour milk cheese, **581**
Sour soils, **42**
Souring of milk, **565**
South Devon (Hams) cattle, **497**
— — sheep, **525**
Southdown sheep, **518**
Sowing grass seeds, **285**
Sow-thistle (*Sonchus* spp.), 213
Spade, **92**
Sparrow-hawk, **617**
Spawn (of mushroom), **383**
Spearwort (*see* Buttercups)
Species, **469**
— origin of, **471**
Speedwell (*Veronica* spp.), **268**
Spergula arvensis, L. (*see* Spurrey)
Sperm (spermatozoon), **451**
Sphærotheca mors-uvæ, Berk. et Curt. (*see* American gooseberry mildew)
Spiders, **644**
Spikelets, **223**
Spinach (*Spinacia oleracea*, L.), **216**
Spiræa Ulmaria, L. (*see* Meadow-sweet)
Splint-bones, **414**, **417**

SPO

Spongy tissue, 157
Spore, 384
Sporidium, 388
Spraying apparatus, 643
Spring cultivation, 100
Spurious fruits, 177
Spurrey (*Spergula arvensis*, L.), 135, 188
— crop, 189
Stables, 490
Stacker, 77, 299
Stacks, 319
Staggers, 652
Stamen, 162
Staminate flowers, 171
Standard, 168
— trees, 361
Starch, 158, 432
Starling, 43, 617
Starters, 565
Steam cultivation, 69
— cultivator, 70
— drag-harrow, 70
— engine, 85
Steamed bone, 113
Steapsin, 434
Stearin, 455
Stellaria spp. (*see* Stitchworts); *S. media*, L. (*see* Chickweed)
Stem, 148
Sternum, 411
Stifle joint, 416
Stigma, 163
Stilton cheese, 577
Stilts, 48
Stinging insects, 622
Stinking chamomile (*Anthemis Cotula*, L.), 213
Stipule, 156
Stitchworts (*Stellaria* spp.), 187
Stoat (*Putorius erminea*), 611
Stock (*Matthiola* spp.), 179
Stock (fruit), 376
— (of seed), 276
Stolon, 150, 222
Stoloniferous, 151
Stomach, 408, 425, 427
Stomata, 158
Stone flies, 634

SUM

Stone fruit, 176, 203, 367
— mill, 91
Stones, 17, 29, 33, 38
Stook, 318
'Store,' 543
— cattle, 511
Straw, 109, 302, 389
— as food, 461
— crops, 178
Strawberry (*Fragaria vesca*, L.), 151, 161, 374, 383
'Strippings,' 553
Strongyle, armed (*Strongylus armatus*), 647
— giant (*Eustrongylus gigas*), 647
— sheep (*Strongylus contortus*), 647
Structure of soil, 22
— and functions of farm animals, 407
Struggle for existence, 471
Stud book, 480
Style, 163
Subsoil, 1, 8, 27
— plough, 61
Sub-species, 470
Subterranean stems, 151
Succory (*see* Chicory)
Succulent foods, 459
Sucker, 154, 383
Sucking roots, 269
Suet, 455
Suffolk horses, 487
— pigs, 540
— sheep, 521
Sugar, 148, 432
— beet (*Beta vulgaris*, L.), 147
— cane (*Saccharum officinarum*, L.), 222
— crops, 378, 460
Sulphate of ammonia, 119, 274
— of copper, 274, 392, 399
— iron, 274
— of lime, 122
—of potash, 121
Sulphates, 13, 34
Sulphur, 646
Sulphuric acid, 18
Summer cultivation, 101

Summer pruning, 376
— rick, 299
Sundew (*Drosera* spp.), 3
Sunflower (*Helianthus annuus*, L.), 135, 159
Superior, 166
Superphosphate, 114
Supine, 412
Surface caterpillars, 626
— feeder, 146
— tension, 24
— weeds, 273
Survival of the fittest, 472
Suspension, 6, 30
Sussex cattle, 498
Swallows, 618
Swathe, 296
— turner, 76, 296
Swede (*Brassica napobrassica*, Mill.), 160, 180
— crop, 124, 181, 338
— as food, 460
Sweep-rake, 299
Sweetbread (*see* Pancreas)
Sweet-grass, floating (*Glyceria fluitans*, Br.), 250
— reed (*G. aquatica*, Sm.), 250
Sweet rocket (*Hesperis matronalis*, L.), 179
Swifts, 617
Swine, breeds of, 535
Swing ploughs, 59
Switch-bill, 97
Sycamore (*Acer Pseudoplatanus*, L.), 135
Symbiosis, 41
Symphysis pubis, 412
Symphytum asperrimum, Donn. (*see* Comfrey, prickly); *S. officinale*, L. (*see* Comfrey, common)
Syncarpous, 167
Synovial fluid, 414
Syrphidæ, 632
Systemic circulation, 441

TACHINIDÆ, 632
Tadpoles, 609

Tail vertebræ, 410
Talpa europæa (*see* Mole)
Tamworth pigs, 538
Tapeworms (*Cestoda*), 651
Tap-root, 145
Taraxacum officinale, Wigg. (*see* Dandelion)
Tare (*see* Vetch)
Tarsal bones, 416
Tarsus, 416
Teat, 548
Tedder, 76
Tedding, 297
Teleutospore, 387
Temperature,
— of germination, 28, 129
— of the soil, 28
Temporary grass land, 279, 289
Tendon, 424
Tendril, 150
Tephritis onopordinis (*see* Celery fly)
Termites, 634
Testa, 128
Testacella, 609
Texas fever, 645
Texture of soils, 2
Thallophyta, 383
Thermometer, 568
Third trochanter, 416
Thistle (*Carduus*, *Carlina*, and *Onopordon* spp.), 213
Thomas phosphate, 117
Thoracic duct, 442, 449
— vertebræ, 410
Thorax, 408
Thorn-apple (*Datura Stramonium*, L.), 214
Thoroughbred, 480, 481
Thousand-headed kale, 183
— crop, 185, 345
Threshing, 320
— machine, 80
Thrips, 633
Throw-back, 473
Thrushes, 618
Thyme (*Thymus vulgaris*, L.), 215
Tibia, 416

Ticks, 645
Till, 6
Tillage, 46, 97
Tillering, 249
Tilletia Caries, Tul. (*see* Bunt)
Tilth, 25, 98, 101, 103, 284, 323
Timothy grass (*Phleum pratense*, L.), 254
Tipula oleracea (*see* Cranefly)
Tits, 617
Toad-flax (*Linaria vulgaris*, Mill.), 268
Toads, 609
Tobacco (*Nicotiana Tabacum*, L.), 214, 643
Toe (of hoof), 419
Tomato (*Solanum Lycopersicum*, L.), 214
Tongue-grafting, 378
Tooth and brush pinion drills, 68
Top-dressing, 119, 122
Torilis spp. (*see* Hedge parsley)
Torus, 162
Trachea, 442
Tracheæ, 636
Traction engine, 85
Tractors, 657
Transpiration, 25, 30, 158
Transplanting, 345
Transported soil, 6, 8
Trapezoid bone, 443
Tree-creeper, 617
Tree-guard, 364
Trefoil, or Yellow clover (*Medicago lupulina*, L.), 197
— crop, 349
Trench ploughing, 61
Trichina (*T. spiralis*), 648
Trichinosis, 648
Tricuspid valves, 439
'Trifolium' (*see* Crimson clover)
— crop, 195
Trifolium hybridum, L. (*see* Alsike clover); *T. incarnatum*, L., and var. *album* (*see* Crimson clover); *T. medium*, L. (*see* Zigzag trefoil); *T. minus*, Sm. (*see* Yellow suckling clover); *T. pratense*, L. (*see* Red clover); *T. pratense perenne*, L. (*see* Cow grass); *T. procumbens*, L. (*see* Hop trefoil); *T. repens*, L. (*see* White clover)
Trigonella ornithopodioides, DC. (*see* Fenugreek)
Tripe, 427
Triticum caninum, Huds. (*see* Wheat-grass, bearded); *T. repens*, L. (*see* Couch grass); *T. vulgare*, L. (*see* Wheat)
Trochanter, third, 416
Trotting horse, 483
Truss, 302
Trussing poultry, 602
Trypanosomes, 654
Tryphaena pronuba (*see* Yellow underwing moth)
Trypsin, 434
Tsetse fly (*Glossina morsitans*), 631
Tuber, 151
Tubular florets, 143, 210
Tulip (*Tulipa* spp.), 155, 170
Turkeys, 590, 601
Turnip (*Brassica Napus*, L.), 132, 147, 152, 160, 181
— blossom beetle, 620
— club-root, 403
— crop, 24, 181, 339
— cutter, 91
— diamond back moth (*Plutella cruciferarum*), 627
— flea beetle, or 'fly' (*Phyllotreta nemorum*), 620
— as food, 457, 465
— gall weevil (*Ceutorhynchus sulcicollis*), 620
— green fly (*Aphis rapæ*), 629
— moth (*Agrotis segetum*), 627
— pulper, 91
— rust, 401
— sawfly (*Athalia spinarum*), 623
— white rot, 405
Turn-wrest plough, 59

Tussock **grass** (*see* **Hair grass**, *tufted*)
Tyrosin, **431**

UDDER, 548
Ulex europœus, L. (*see* Gorse)
Ulmus campestris, Sm. (*see* Elm)
Ulna, **412**
Umbel, *204*
Umbelliferæ, 155, **204**
Unciform bone, 413
Underground stems, 151
Ungulata, 422
Unicellular, 654
Unisexual flowers, 171
Urea, 110, 446
Uredospore, 387
Ureter, 446
Urethra, 446
Urinary bladder, **446**
— tubules, 446
Urine, 446
Urticaceæ, 219
Ustilago avenæ, Jens. (*see* Smut, oat); *U. nuda*, Jens., and *U. tecta*, Jens. (*see* Smut, barley); *U. tritici*, Jens. (*see* Smut, wheat)

VACCINIUM MYRTILLUS, L. (*see* Whortleberry)
Vagus nerve, **450**
Value, manure, of foods, 466
Valves (of heart), 437
Variation, **472**, **495**
Variety, **469**
— fruit, **366**, 367, **373**
Vascular bundles, **148**, **156**, 157
— cylinder, *144*
Vaso-motor nerves, **451**
Vat, cheese, 572
Veal, 547
Vegetable marrow (*Cucurbita ovifera*), **135**, **204**
Vegetative organs, **160**
— reproduction, 155
Vein, **437**
— of leaf, *156*
Vells, 428, 591
Venous blood, **437**
Vent, 427
Ventilation,
Ventral, 408
— suture, 169
Ventricle, 436
Venus' comb (*see* Shepherd's needle)
Verbascum Thapsus, L. (*see* Mullein)
Vernal grass, Puel's (*Anthoxanthum Puelii*, Lecoq et Lamotte), 253
—, sweet-scented (*A odoratum* L.), 251
Vertebra, 408, 422
Vertebral column (*see* Backbone)
Vertebrata, 407, 422
Vetch or tare (*Vicia sativa* L.), 132, 159, 199
— crop, 246
— as food, 465
Vexillum, 168
Vicia spp. (*see* Vetch)
Villus, 447
Vine (*Vitis vinifera*, L.), 150
Viola tricolor, L. (*see* Pansy)
Violet (*Viola* spp.), 135
Viper's bugloss (*Echium vulgare*, L.), 216
Virginia creeper, 150
Virus (for rats, &c.), **613**
Volcanoes, 7
Voles, **613**

WADS, 331
Waggons, *79*
Wagtails 617
Wall (of hoof), 419
Wallace, Alfred Russel, 471
Wallflower (*Cheiranthus Cheiri*, L.), 179
Walnut (*Juglans regia*, L.), 13
Warble fly, **632**

Warblers, 618
Warping, 42
Wart disease (*see* Black scab)
Wasps, 622
Waste product, 141; of the soil, 23, 34
Water, 5
— culture, 148
— dropwort (*Œnanthe fistulosa*, L.), 209
— glass, 452, 605
— meadows, 281
— parsnip (*Sium angustifolium*, L., and *S. latifolium*, L.), 209
— table, 25, 44
Watercress (*Nasturtium officinale*, L.), 187
Watson, Hugh, of Keiller, 500
Way bent (*see* Barley, wall)
Weasel (*Putorius vulgaris*), 611
Weathering, 8
Webbed seeds, 243
Weeds, 42, 43, 264
Weevils, 620
Weighbridge, 511
Weismann, 473
Welsh cattle, 498
— mountain sheep, 528
— runts, 498
Wensleydale sheep, 529
Wet rot of potatoes (*Clostridium butyricum*), 405
— seasons, 32, 138
Wheat (*Triticum vulgare*, L.), 130, 132-4, 145, 159
— bulb fly (*Hylemyia coarctata*), 632
— bunt, 393
— crop, 32, 123, 310, 315
— as food, 457, 459, 465
— grain, 132-4
— harvesting, 317
— manures for, 123
— midge (*Cecidomyia tritici*), 632
— rust, 386
— straw as food, 457, 461, 465

Wheat-grass, bearded (*Triticum caninum*, Huds.), 258
Wheel ploughs, 59
Wheels of carts, 79
Whetstone, 95
Whey, 552, 571
Whin (*see* Gorse)
Whip-grafting, 378
Whippletrees, 49
White bryony (*Bryonia dioica*, L.), 204
White cabbage butterflies (*Pieris* spp.), 627
— clover (*Trifolium repens*, L.), 161, 192
— corpuscle, 435
— rot, turnip (*Pseudomonas destructans*, Potter), 405
— rust (*Cystopus candidus*, Lev.), 400
White currant, 381
White-faced sheep, 514
Whorl, 167
Whortleberry (*Vaccinum Myrtillus*, L.), 3
Wild duck, 588
— goose 589
— turkey (*Meleagris gallopavo*), 590
Willow, 161
Wiltshire horned sheep, 520
Wind-flower (*see* Anemone, wood)
Windpipe, 442
Wind pollination, 171
Wind-row, 298
Wind-screens, 29
Wing, 168
Winnowing machines, 87
Winter barley crop, 100
— cap, 315
— cultivation, 100
— moth (*Cheimatobia brumata*), 627
— oats crop, 100
— ploughing, 100
Wireworms, 620
— false, 646
Woad (*Isatis tinctoria*, L.), 179

WOO ZOO

Wood, 144, 156
— leopard moth (*Zeuzera æsculi*), 627
— wasp (*see* Giant sirex)
Woodlice, 610
Wood-rush, field (*Luzula campestris*, Willd.), 228
Wool, 513
— waste, 120
Woolly aphis (*Schizoneura lanigera*), 630
— currant scale (*Pulvinaria ribesiæ*), 630
Work, 456, 488
Working animals, 456, 488
Wren, 618
Wrist, 413

YARDS, covered, 109
Yarrow (*Achillea millefolium*, L.), 135, 161, 210
Yeaning, 533
Yeast (*Saccharomyces Cerevisiæ*), 384
Yellow clover (*see* Trefoil).
— rattle (*Rhinanthus Crista galli*, L.), 268
— suckling clover (*Trifolium minus* L.), 196
Yellow underwing moth (*Tryphæna pronuba*), 627
Yew, 3
Yorkshire fog (*Holcus lanatus*, L.), 259
— pigs, 535

ZEA MAYS, L. (*see* Maize)
Zebroid, 470
Zeuzera æsculi (*see* Wood leopard moth)
Zigzag trefoil (*Trifolium medium*, L.), 196
Zoospore, 398, 403, 404